A SYSTEMS DEVELOPMENT METHODOLOGY FOR THE AUSTRALIAN ARMY

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MASTER OF MILITARY ART AND SCIENCE

by

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The organisations involved in the concept and acquisition phases of the material cycle are examined. The study proposes that the key organizations for Army are the Combined Arms Training and Development Center, the Land Development Branch within the Capability Development Division, the Capability Programming and Resource Planning Division, and the Defence Acquisition Organisation.

Key documentation in the concept and acquisition phases of the material cycle is identified. The study proposes that the key organizations apply the systems development methodology to the production of key documentation in the concept and acquisition phases of the material cycle.

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ABSTRACT

A SYSTEMS DEVELOPMENT METHODOLOGY FOR THE AUSTRALIAN ARMY by MAJ Gregory P. Walters, Australia, 92 pages

This study develops a methodology for the Australian Army to adopt to ensure that a systems approach is applied to the concept and acquisition phases of the Materiel Cycle. This involves an integration of Systems Engineering, Integrated Logistics Support, and Logistics Support Analysis. The study examines each of these disciplines separately before considering their relationship with one another. A methodology is then produced which integrates these disciplines.

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LIST OF ABBREVIATIONS

ADF	Australian Defence Force
C3I	Command, Control, Communications and Intelligence
CATDC	Combined Arms Training and Development Centre
CMIT	Capability Management Improvement Team
CPP	Capability Programming and Plans
CPRP	Capability Programming and Resource Planning Division
DAMS	Director Acquisition Management System
DAO	Australian Defence Acquisition Organisation
DCC	Defence Capability Committee
EAS	Equipment Acquisition Strategy
FELSA	Front End Logistic Support Analysis
HQADF	Headquarters Australian Defence Force
ILS	Integrated Logistics Support
IAP	Investment Analysis Program
ITR	Invitation to Register Interest
LOGMAN	Logistic Support Manual
LSA	Logistic Support Analysis
NSD	National Support Division
RFT	Request for Tender
SER	Source Evaluation Report
SEWP	Systems Engineering Working Party

CHAPTER 1

INTRODUCTION AND OVERVIEW

On 6 July 1998, Admiral C. A. Barrie, the incoming Chief of the Australian Defence Force, issued a message to all Australian Defence Force members,[1] cosigned by the senior members of the Defence Executive. In it he called for a fundamental review of all capability processes, and for the development of appropriate processes and systems that would see a capability managed throughout its entire life, “from the first bright idea, through force development, acquisition, in-service usage, until disposal.”[2] The challenge was to determine what methodology the Australian Defence Force should adopt to ensure that a systems approach was applied throughout a capability’s life cycle.

Studies conducted by the US DOD[3] of defence projects over the past twenty years examined the process of taking a capability from its initial conception through to fielding in service. They showed that if a change to increase supportability were made during the design process and cost $1.00, that same change made during production would cost $100,000. If the change was not made until after introduction, the cost would escalate to $1,000,000.

The need for effective capability development is also important to the warfighter because it directly affects their ability to prosecute war. If the requirements for a new system are inadequately defined then the warfighter’s needs will not be met and it will only be after an equipment is introduced into service that they will find it does not do what they want it to do. Furthermore, they are likely to find that they can not fight with it because it does not meet their concept of operations; they do not have the resources to

support it; and it places an additional maintenance burden on their already stretched resources. If the system requirements are unnecessarily over-specified then the system is almost guaranteed to cost more, which means that he either receives less of that equipment or less of another required capability. Either way the warfighter loses.

Problem Statement

This study examines the process of developing and acquiring a capability for the Australian Army. It develops a methodology for implementing a systems approach in the concept and acquisition phases of the materiel cycle.

In developing the methodology, the study examines the use of Systems Engineering, Integrated Logistics Support (ILS) and Logistic Support Analysis (LSA). ILS and LSA are already established as part of the capability development and acquisition process. They are used throughout defence to ensure a systematic approach is taken to developing the logistics requirements for a new capability. Systems Engineering is not as well developed.

The reason for examining Systems Engineering is that the Australian Defence Acquisition Organisations (DAO) commissioned a study titled the *DAO Systems Engineering Study*, to assess the implementation of Systems Engineering within its organisation. The report recommended that Systems Engineering processes and procedures be adopted across the three services within the acquisition phase of the materiel cycle. The Army's Combined Arms Training and Development Centre (CATDC) also decided to use Systems Engineering software to manage its requirements

development process. Both of these are key organisations within the concept and acquisition phases.

This study examines how Systems Engineering, ILS and LSA can be integrated to produce a systems development methodology for the Australian Army which can be applied in the concept and acquisition phases of the materiel cycle.

Research Question

What methodology should the Australian Army adopt to ensure that a systems approach is applied to the concept and acquisition phases of the materiel cycle?

Background

There is currently no formal methodology within the Australian Army for implementing a systems approach in the capability development and acquisition phases of their materiel cycle. The methodology that the US uses is based on the Systems Engineering approach, to which ILS and LSA are applied.

The Systems Engineering process used in the US DoD has historically been based on various evolutions of MIL-STD-499, *System Engineering Management*. The standard was developed to integrate with the US DoD acquisition system. However, the four phases of the Australian Defence materiel cycle do not match the US DoD Acquisition process. The US standard, therefore, could not be applied to the Australian Defence materiel cycle without being tailored to meet the needs of the Australian system.

In the US DoD the use of ILS has traditionally been based on MIL STD 1388 and the use of LSA has been based on MIL STD 1388 1A and MIL STD 1388 2B. These standards are still used within the Australian Defence Force.

The Defence Acquisition Organisations and the Combined Arms Training and Development Centre are increasingly aware of the use of Systems Engineering in the capability development and acquisition phases of an equipment's life cycle. However, at present within the Australian Army, Systems Engineering principles are only applied in an ad hoc manner.[4] The implementation of these principles is usually as a result of the efforts of a particular desk officer, and the results are usually limited to their project or area of development. There exists no policy for the implementation of Systems Engineering within the Australian Army, no formal requirement for its use, and no champion for its implementation.

The *DAO Systems Engineering Study* examined the integration of Systems Engineering across the three services within the DAO. This study was defence wide and applied only to the acquisition phase of the materiel cycle. There has been no study conducted to look at how the Australian Army can apply a systems approach in both the concept and acquisition phases of the materiel cycle.

Study Method

There are three areas that are well defined in the current body of knowledge. They are Systems Engineering, ILS and LSA. This study will examine the existing documentation in these areas with a view to providing a synthesis, which can be applied within the Australian Army.

The first step is to examine the Australian Army's materiel processes to determine the context within which this synthesis can be applied. This examination includes the

materiel cycle, key documentation requirements, the approval process, and the role of committees.

Systems Engineering, ILS and LSA are then examined separately followed by an examination of the relationship between each of these disciplines. Particular emphasis is placed on the relationship between LSA and Systems Engineering.

This analysis provides the basis for detailing a methodology for the Australian Army to implement a systems approach in the capability development and acquisition phases of the materiel cycle.

Systems Development Disciplines

The two major disciplines that will be examined are Systems Engineering and ILS. LSA will be examined because it is the tool that integrates ILS and the engineering functions. Project management is discussed because it is the discipline that applies the skills to manage the capability development and acquisition process.

Systems Engineering is an interdisciplinary approach that aims to deliver systems providing an optimum, balanced, coherent solution to satisfy customer needs. It is an orderly, structured, disciplined, and systematic process. It attacks large problems by breaking them down into smaller ones, and ensures that the solutions of the smaller problems are integrated into the solution of the larger problem. An important aspect of this process is traceability and accountability. The process examines all of the elements that interface with a system. In this way it seeks to optimize the quality of a system throughout its entire life cycle.

As applied to an Army equipment system, Systems Engineering includes but is not limited to, capability development, project management, engineering, and logistics. Striking an optimum, balanced, and coherent solution means making sound trade-offs between capability and supportability, acquisition and life cycle support, and quantity versus quality.

Systems engineering is a management or problem-solving approach, rather than a technical approach, even though there are specific standards that outline its implementation. It is comprised of the following key activities, which are applied iteratively to successive layers of the system:

a. Requirements Analysis. This analyses the requirements to ensure they are complete, understandable and traceable.

b. Functional Analysis/Allocation. This breaks down the system to the next layer of definition and allocates the requirements to the system's functional components.

c. Design Synthesis and Verification. This translates the requirements into possible solutions and evaluates the progress of the evolving system and its effectiveness at meeting the original requirements.

d. Systems Analysis and Control. This evaluates each alternative in terms of its capability to meet the requirements and then selects the optimal one. The process is monitored and controlled to ensure that it is still meeting the original intent for which it was designed.

ILS is another whole of life management discipline that aims to deliver a complete system that meets the user's needs. It aims to integrate all support and service considerations for a materiel system and provide a seamless transition of support activities between each phase of the materiel cycle.

Within the concept and acquisition phases, ILS aims to ensure that:

a. consideration of support factors is integral to the development of capability options,

b. support considerations influence design requirements and selection,

c. requirements are used in optimizing a materiel system's performance,

d. support elements are acquired or implemented.[5]

LSA is the tool that integrates ILS and the engineering functions. It is made up of a series of tasks that when performed ensure that each element of ILS is considered along with the system design. LSA provides a single analytical approach to enable support considerations to influence the design requirements and design selection for a materiel system.

Project management is a discipline to manage the capability development and acquisition process. As such, Systems Engineering, project management and ILS are interrelated. The intelligent and tailored application of good Systems Engineering, project management and ILS principles has proven to help bring projects in on schedule, within budget and with optimal life-cycle cost. It also helps to satisfy end users' and environmental requirements, and to consider all relevant constraints.

The Australian Defence Force's approach to capability development and acquisition incorporates Systems Engineering, project management and ILS principles, but not systematically or consistently. The Australian Defence industry has pointed out that essential elements of the approach are either missing or not applied properly. In most cases the failure is due to an ill-defined statement of requirements and inadequate management of the scope of the project. Project budgets, human resource requirements, and schedules are often derived without a sufficiently systematic, rigorous, or auditable approach. They often lack a proper application of work linked to resource requirements. These failures result largely from systemic problems rather than failures on the part of individuals.

There is currently no Australian Defence Force or Australian Army policy document that ties Systems Engineering, project management, and ILS together, nor is there a document that addresses the integration of Systems Engineering across the Australian Defence Force or Army. Prior to the *DAO Systems Engineering Study* completed in 1999, the Defence Systems Engineering Working Party conducted a study to investigate the applicability of Systems Engineering within defence. They recommended the adoption of Systems Engineering. Their draft report was tabled in November 1996.

Scope

This study proposes a methodology for the Australian Army to ensure that a systems approach is applied to the capability development and acquisition phases of the materiel cycle. It focuses on the integration of Systems Engineering, ILS, and LSA

within the concept and acquisition phases of the Australian Army's materiel cycle. It will not examine the in-service or disposal phases.

This study considers the organisational aspects of integration and will use non-software projects as a basis for discussion. It will not examine the use of specific Systems Engineering tools or products nor attempt to conduct a detailed cost benefit analysis of the implementation of the Systems Engineering approach.

Assumptions

The DAO Systems Engineering study and the earlier work done by the Defence Systems Engineering Working Party in 1996 determined that there was benefit in applying the Systems Engineering approach to the Australian Defence Force. US DoD Instruction 5000.2-R mandates that Systems Engineering be applied throughout a system's life cycle. It states, "The Program Manager shall ensure that a Systems Engineering process is used to translate operational needs and/or requirements into a system solution that includes the design, manufacturing, test and evaluation, and support processes and products."[6]

The Australian Defence Instruction (General) LOG 03-6 [DI(G) LOG 03-6] directs that, "As supportability is an integral component of performance, ILS principles and practices will be applied to projects during both the pre-approval and acquisition phases to ensure that materiel systems are acquired that meet performance specifications at minimum life cycle costs."[7] It also states that, "Systems Engineering and ILS, when combined, provide a life cycle focus for managing the design and support efforts (for a system or modification to a system)."[8]

It is therefore assumed that the tailored application of good Systems Engineering, project management and ILS principles assist with bringing projects in on schedule, within budget, and with optimal life-cycle cost. It also is assumed that these assist in satisfying end users' needs and environmental constraints and that the process allows the consideration of all relevant constraints and impacts. Finally, it is assumed that the Australian Army will benefit from the implementation of a systems approach in the concept and acquisition phases of the materiel cycle.

Key Terms

Definitions of key terms come from the engineering standard EIA/IS 632. Additional definitions are provided for clarity. Key terms include:

Systems Engineering

Engineering standard EIA/IS 632: defines Systems Engineering as:

> An interdisciplinary approach encompassing the entire technical effort to evolve and verify an integrated and life cycle balanced set of system people, product and process solutions that satisfy customer needs.
>
> Systems Engineering encompasses:
>
> a. the technical efforts related to the development, manufacturing, verification, deployment, operations, support, disposal of, and user training for, system products and processes
>
> b. the definition and management of the system configuration;
>
> c. the translation of the system definition into work breakdown structures;
>
> d. the development of information for management decision making.[9]

The *DAO Systems Engineering Study* provides a definition based on EIA/IS 632. It defines Systems Engineering as:

> The conduct of engineering based on systems principles. Good practice is characterized by an interdisciplinary approach encompassing the entire technical effort to evolve and verify an integrated and life-cycle balanced set of system product, people and process solutions that satisfy customer needs. Systems Engineering encompasses:

a. the definition and management of the system configuration;
b. the translation of the system definition into work breakdown structure for management purpose; and
c. development of information for use by stakeholders other than the performing entity.[10]

IEEE Std 1220-1994 defines Systems Engineering as an interdisciplinary collaborative approach to derive, evolve, and verify a life cycle balanced system solution that satisfies customer expectations and meets public acceptability.

Systems Engineering Process

EIA/IS 632 defines the Systems Engineering process as:

> A comprehensive, iterative, problem solving process that:
> a. transforms validated customer needs and requirements into a description of a life cycle balanced solution set of people, products and processes;
> b. generates information for decision makers;
> c. provides information for follow-up technical efforts.[11]

The *DAO Systems Engineering Study* provides a definition based on EIA/IS 632. It defines the Systems Engineering process as:

> A comprehensive, iterative, problem solving process that:
> a. identifies and validates customer/tasking entity needs and requirements;
> b. transforms validated customer/tasking entity needs and requirements into a description of a life-cycle balanced solution set of products, processes and people;
> c. generates information for decision making; and
> d. provides information for follow-on technical efforts.[12]

Key Systems Engineering Activities

EIA/IS 632 defines the four key Systems Engineering activities as requirements analysis, functional analysis/allocation, design synthesis and verification, and system analysis and control. The definitions of each of these activities are as follows:

a. Requirements Analysis. Requirements Analysis is the determination of system specific performance and functional characteristics based on analyses of customer needs, requirements, and objectives; missions/operations; projected utilisation environments for people, products, processes; constraints; and measures of effectiveness. It is the bridge between customer requirements and system specific requirements from which solutions can be generated for the primary system functions.

b. Functional Analysis/Allocation. Functional Analysis/Allocation is the examination of a detailed function to identify all the sub-functions necessary for the accomplishment of that function, identification of functional relationships and interfaces (internal and external) and capturing of these in a functional architecture. It includes the flowdown of upper level performance requirements and assignment of these to lower level sub-functions.

c. Design Synthesis and Verification.

1. Synthesis. Synthesis is the translation of input requirements (including performance, function and interface) into possible solutions (resources and techniques) satisfying these inputs. It defines a physical architecture of people, product and process solutions for logical groupings of requirements (performance, function and interface) and then designs these solutions.

2. Verification Function. The verification function includes the tasks, actions, and activities to be performed to evaluate progress and effectiveness of evolving system (people, product and process) solutions and to measure

compliance with requirements. Analysis (including simulation), demonstration, test, and inspection are verification approaches used to evaluate risk; people, product, and process capabilities; compliance with requirements; and proof of concept.

d. System Analysis and Control. System Analysis and Control is the imposition of structure and discipline into a system evolution by measuring progress based on demonstrated performance; identifying, developing and examining alternatives; making decisions based on cost, schedule, performance, and risk to effect balanced results; documenting the evolution and rationale, and controlling resulting configurations.

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[1]Admiral Barrie stated, "We are going to ensure that Defence manages whole of life capability through seamless management. . . . We will establish the appropriate underlying processes and systems needed for this. . . . The result will be that our systems meld together all of the elements that go into building an effective defence force."

[2]Admiral C. A. Barrie et al., *A Message to all Defence Personnel from the Executive*, letter Australian Defence Force, Canberra, 6 July 1998.

[3]K. Gascoyne and P. King, *ILS Awareness Course--Student Notes*, (Canberra: Computer Power and Total Logistics Management, 28 March 1996), 2.

[4]Based on the authors own observations and the findings of the "DAO Systems Engineering Study" (1999) and the findings of the "Study of the Applicability and Application of Systems Engineering within Defence--Final Draft" (Nov 1996).

[5]Australian Department of Defence, *Defence Instruction (General) LOG 03-6 - Defence Policy on Integrated Logistics Support*, (Canberra: Commonwealth of Australia, 26 May 1997), 1.

[6]US DoD Instruction 5000.2, *Mandatory Procedures for Major Defence Acquisition Programs (MDAPs) and Major Automated Information System (MAIS) Acquisition Programs*, (Washington DC: US DoD, 15 March 1996), Part 4, Section 4-3, 1.

[7]Australian Department of Defence, *Defence Instruction (General) LOG 03-6*, 2.

[8]Ibid., Annex B, B-1.

[9]Australian Department of Defence, *Draft Defence Instruction (General) LOG 08-XX The Application of Systems Engineering in Capital Equipment Acquisition and In-Service Support*, (Canberra: Commonwealth of Australia, 12 December 1996), Annex A, 1.

[10]Technology Australasia, Standard No 001, *Systems Engineering*, Issues 3, 20 September 1996, 14.

[11]Australian Department of Defence, *Draft Defence Instruction (General) LOG 08-XX*, Annex A, 1, 2.

[12]Technology Australasia, 15.

CHAPTER 2

REVIEW OF LITERATURE

Systems Engineering

This study considered three major Systems Engineering Standards. They are:

a. MIL-STD 499B, *Systems Engineering*, Draft 06 May 92;

b. EIA/IS 632, *US Electronic Industries Association Interim Standard 632*, dated December 1994; and

c. (3) IEEE Standard 1220-1994, *US Institute of Electrical and Electronics Engineers Trial-Use Standard for Application and Management of the Systems Engineering Process*, dated February 1995.

To date the use of systems engineering within the ADF has followed the US model as defined in military standards MIL-STD-499/A/B even though MIL-STD-499B was never officially released. When it became clear in June 1994 that MIL-STD 499B (Draft) was not going to be released by the US government as a result of a move away from the use of military standards, the US Electronic Industries Association agreed to undertake the task of "demilitarizing" the document and releasing it as an industry standard. As a result, MIL-STD-499B was converted into the commercial standard EIA/IS-632 1994, *Systems Engineering*. The purpose of this standard was to aid the integrated development, realization, or improvement of system products and processes. It also set out to help developers:

a. identify and balance the competing requirements between different stakeholders;

b. establish and develop technical requirements;

c. ensure that technical requirements were met within cost, schedule and risk constraints; and

d. provide products that met stakeholders' needs.

As EIA/IS-632 was based on a military standard, it was necessary to create a standard that was more appropriate to the commercial application of Systems Engineering. As a result IEEE 1220-1994, *IEEE Trial-Use Standard for Application and Management of the Systems Engineering Process,* was released in 1995. It is significantly different from EIA/IS-632, even though the basic higher level processes are quite similar. Its purpose was to provide a standard for managing a system from initial concept through development, operations, and disposal, and it focuses on the systems engineering process. IEEE 1220 gives a more detailed treatment of both systems engineering process tasks and life cycle phases than EIA/IS 632.

Both of these standards are currently being reviewed. An international standard for system life cycle processes, ISO 15288, is also under development but it is currently unknown when this standard is likely to be released.[1] The development of Systems Engineering standards is shown in figure 1.[2]

Technology Australasia, one of Australia's leading practitioners and educators of Systems Engineering for the ADF, has also produced a systems engineering standard. Issue 3 was released in September 1996. Its intent is, "to assist in defining, performing, managing and evaluating Systems Engineering efforts in system acquisitions and technology-based system developments."[3] It adapts MIL-STD-499B for general application with the intent of improving aspects of the last draft.

A number of companies, such as TDA Systems Engineering, Ball AeroSpace and Technologies, and Technology Australasia, who teach Systems Engineering to Australian Defence personnel, have produced course notes and handbooks on the use of Systems Engineering within the Australian Defence Force. This study has drawn on course materiel from the systems engineering courses run by Technology Australasia in September 1995, TDA Systems Engineering, and Ball Aerospace and Technologies Group in September--October 1997, and TDA Systems Engineering in May 1998.

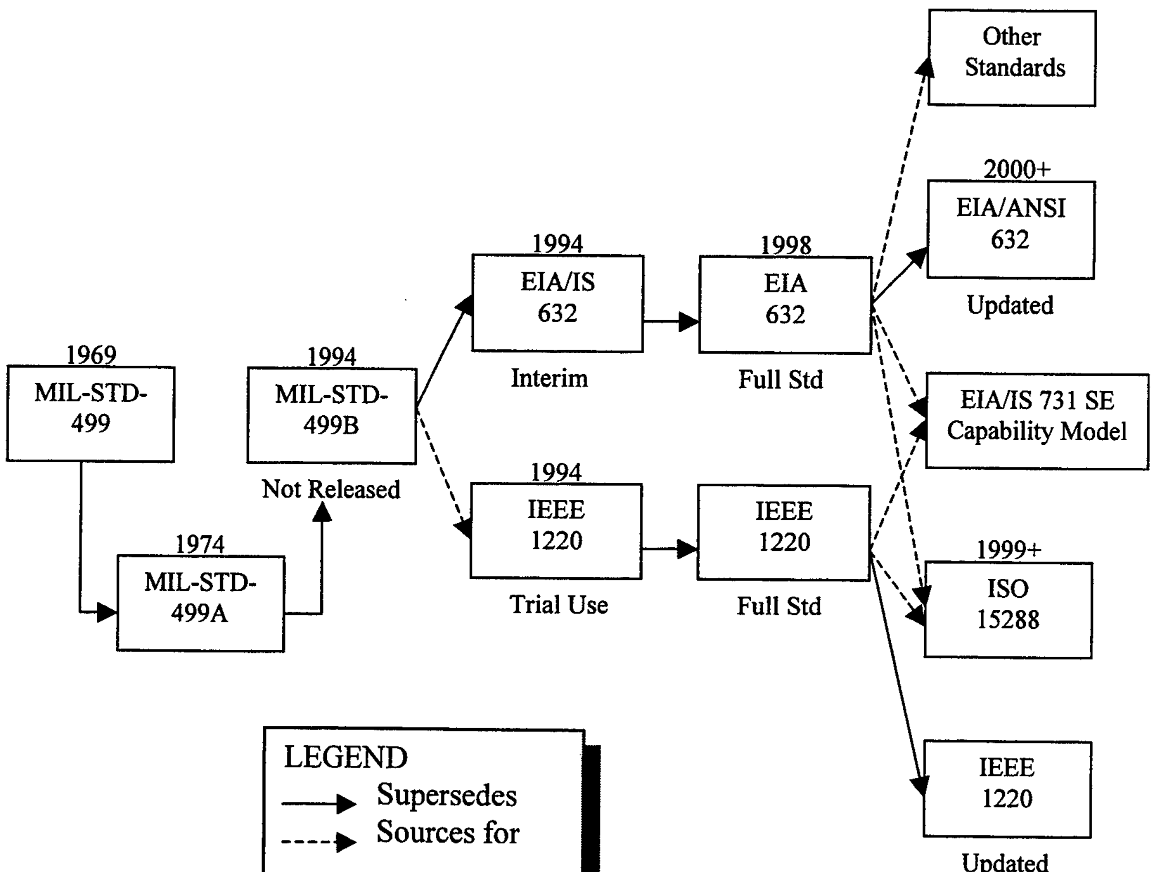

Figure 1. Development of Systems Engineering Standards

There is currently no ADF or Australian Army document that addresses the integration of systems engineering across the ADF or Army. However, a draft report from the Defence Systems Engineering Working Party, which was established to study the applicability and application of systems engineering within Defence, has been produced.

The *DAO Systems Engineering Study*, was undertaken by Technology Australasia under a contract with the Commonwealth of Australia. Its purpose was to assess the implementation of systems engineering within the Defence Acquisition Organisation of the Department of Defence, Commonwealth of Australia. The contract was managed by the Director Acquisition Management Systems (Systems Engineering) (DAMS(SE)).

The overall objective of the study was to determine the appropriate requirements for the successful application of systems engineering in the acquisition of major capital equipment by the Australian Department of Defence. It is therefore limited to the application of systems engineering in major projects in the Defence Acquisition Organisation.

Another major study into systems engineering within defence was conducted in 1995/96 by the Defence Systems Engineering Working Party (SEWP). The SEWP was formed under the direction of the Defence Logistics Policy Consultative Group to study the applicability and application of systems engineering in defence, as a prerequisite to policy development. Its aim was to determine the applicability of Systems Engineering in defence and the most appropriate means of implementing Systems Engineering principles, policy, and procedures. It was completed in approximately twelve months and was based on extensive interviews with stakeholders and projects within the Australian

Department of Defence, defence industry, and providers of systems engineering education and training.

The SEWP study found that Systems Engineering is applicable to defence. It confirmed the need to formalize the application of Systems Engineering principles within defence and recommended the establishment of a Systems Engineering Support Office to carry out a phased implementation strategy. Its final report was not endorsed. It appears that lack of resources to implement the report's recommendations was a major contributing factor.

Within the US, US DoD Instruction 5000.2-R dated 15 March 1996 details the mandatory procedures for Major Defence Acquisition Programs and Major Automated Information System Acquisition Programs. This instruction mandates the use of Systems Engineering.

The Materiel Cycle and Processes

The materiel cycle and processes are documented in the Capital Equipment Procurement Manual (CEPMAN) Volumes One and Two. The Major Capital Acquisition process is also taught by a number of Australian Defence Contractors such as Kinhill Engineering. Handbooks are produced on these courses. This study used materiel from a course on the Major Capital Acquisition Process run by Total Logistics Management and Kinhill Engineers in October 1997.

Integrated Logistics Support

Integrated Logistics Support (ILS) is well covered in numerous articles and books. Defence Instruction (General) [DI(G)] LOG 03-6 provides the Australian Defence Policy on ILS and the Australian Department of Defence Logistic Support

Manual (LOGMAN) provides policy and procedural support on logistic support, including ILS, for use within defence.

Defence contractors run numerous courses for defence personnel on the use of ILS within defence. This study used materiel from an ILS Awareness Course run by the Computer Power Group and Total Logistics Management in October 1996 and a Short ILS Course run by the same companies in May 1997.

There is currently no Australian Defence Force or Australian Army policy document that ties systems engineering, ILS, and the materiel cycle processes together.

Capability Management Improvement Team

In accordance with the CDF's message to all defence personnel on 6 July 1998, DEFGRAM 187/98 (06 August 1998) authorized the formation of a Capability Management Improvement Team (CMIT) to assist in the improvement of capability management within Defence.

The CMIT is to take a broad view of capability, which encompasses whole of life considerations and the principal factors that contribute to effectiveness. The CMIT aims to overcome the current segmentation of capability management that currently exists within defence, and achieve a more seamless life cycle management of capability. The outcomes of the team's study will have a major impact on the nature and implementation of any systems development methodology proposed for defence.

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[1]Technology Australasia, *Defence Acquisition Organisation Systems Engineering Study (Final Report Draft C)*, (Canberra: Technology Australasia, 1 October 1998), 43.

[2]Dr J. Lake, *Presentation--Standards that can help the Engineering of Better Systems*, Brisbane, 5 Nov 98 [Online] available at http://www.vtcorp.com/wma-incose/1997-docs/lakestds.ppt, accessed on 5 Nov 98.

[3]Technology Australasia, Standard No 001, *Systems Engineering,* Issue 3, (Melbourne: Technology Australasia, 20 September 1996), ii.

CHAPTER 3

ORGANISATIONS AND THE MATERIEL CYCLE

The systems development methodology that this study develops is not something fundamentally new, but rather a procedure for applying Systems Engineering within the defence context. To do this successfully, the relationship between Systems Engineering, Integrated Logistics Support (ILS), Logistics Support Analysis (LSA) and other project management methodologies adopted within defence must be stated explicitly for it to be understood and accepted by the relevant authorities. Furthermore any proposed methodology must be placed within the context of the roles of the various organisations involved in the relevant phases of the materiel cycle. This raises a number of immediate questions.

a. What are the organisations involved in the relevant phases of the materiel cycle?

b. What are the phases of the materiel cycle?

c. What is the relationship between Systems Engineering, ILS, LSA, and other project management methodologies within defence?

The first two questions will be dealt with in this chapter and the last question will be dealt with in chapter 4.

Defence Organisations

There are a number of organisations within the Australian Defence Force involved in the development and fielding of a new capability within the army. Each of these organisations could use a systems development methodology, to some extent, in the concept and acquisition phases of the army's materiel cycle. To understand the

application of a systems development methodology, it is first necessary to identify those organisations that would be involved in its application.

The objective of the Headquarters Australian Defence Force Headquarters (HQADF) (Figure 2) is to provide for the higher command and control of the ADF and give advice on strategic policy and long-term Defence planning, the management of international defence relationships and the development of defence capabilities.

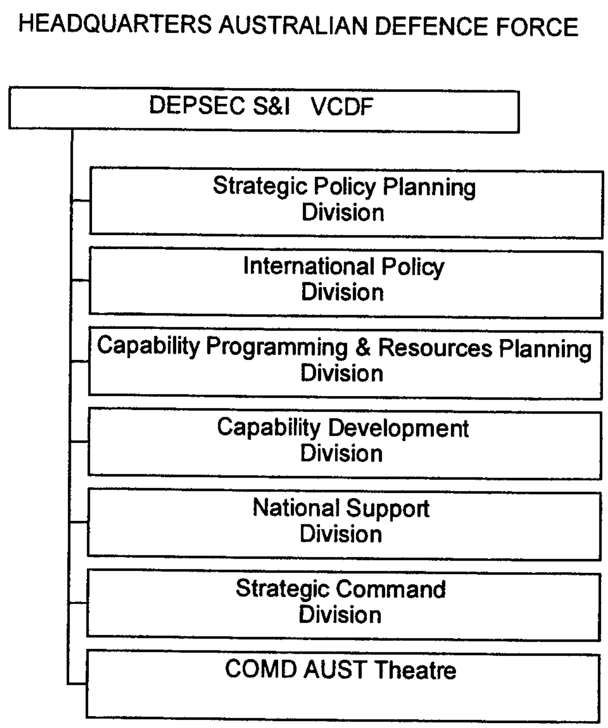

Figure 2. Headquarters Australian Defence Force Organisational Chart

The Strategic Policy Planning Division provides defence's long term vision and therefore the basis for the early stages of capability development. The International Policy Division has little input into capability development but the Capability Programming and Resource Planning Division (CPRP) is very important. The CPRP

controls the initial commitment of funds for any proposed capability and therefore arguably is the most powerful division in the initial stages of capability development. The Capability Development Division is responsible for representing the user and developing the initial capability requirements.

The mission of the newly formed National Support Division (NSD) is to broaden, shape and improve National and International Support capabilities and arrangements to better enable force generation, mobilization and sustainment for the ADF. As a result they aim to comprehensively engage the capability development process to the extent that their input is seen as essential to the presentation of balanced capability development proposals to the decision making bodies.[1] The NSD should provide critical input into the systems development process.

Neither the Strategic Command Division nor the Australian Theatre Command is directly involved in capability development.

<u>Divisions within HQADF</u>

The Strategic Policy Planning Division (figure 3) provides the long-term vision for defence. Of particular relevance to the very early stages in the development of a capability are the Capability Programming and Plans (CPP) Branch, which determines the defence long term plan and the Military Strategy Branch, which develops strategic concepts.

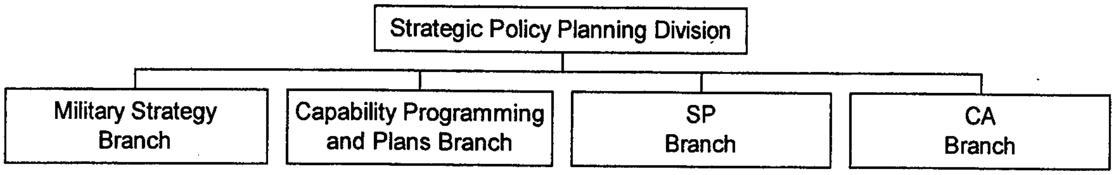

Figure 3. Strategic Policy Planning Division Organisational Chart

The Capability Programming and Resource Planning Division (CPRP) shown in figure 4, controls the initial commitment of funds for major capabilities. The head of the CPRP Division, HCPRP, is the Chair of the Capability Forum and the head of the Investment Analysis Program (IAP) Branch acts as his secretary. The IAP branch therefore prepares the agenda for the Capability Forum and writes up the minutes of the meeting. In this way they control the discussion, the issues presented and the official outcomes of the meeting. The IAP Branch also provides the issues briefs for the Defence Capability Committee. As a result CPRP, particularly the IAP Branch, is perhaps the most powerful and therefore most important player in the early development phase of a capability.

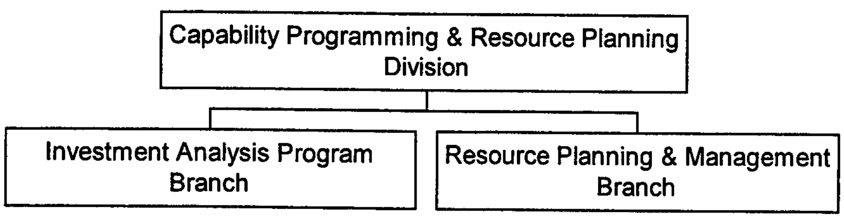

Figure 4. Capability Programming and Resource Planning Division Organisational Chart

The Capability Development Division (figure 5) is responsible for sponsoring all ADF Options Papers and developing Issues Papers dealing with the acquisition of capital

equipment. They work with CPRP in the development of these documents. As the official capability project sponsor, they have responsibilities in the concept and definition stages, and after Government approval of a project. They are also responsible for formulating operational requirements for each capability. They represent the user community and develop the initial capability requirements. As the project sponsor, the Capability Development Division is a key player in the early stages of the materiel cycle.

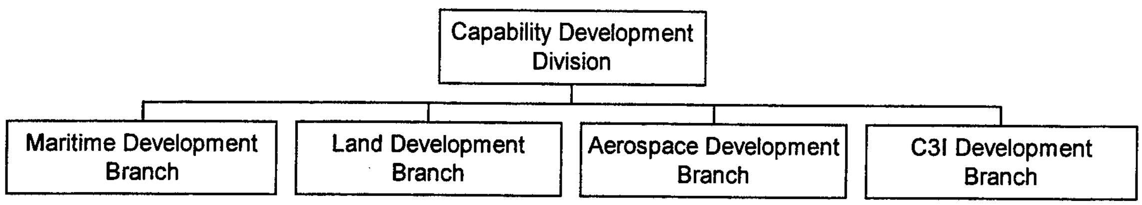

Figure 5. Capability Development Division Organisational Chart

The division has three branches that represent the three services and one branch that deals with command, control, communications and intelligence (C3I) across all services. Of most relevance to the development of army capabilities is the Land Development Branch, which deals with army capabilities. One should note however that capability requirements might come from the other branches, particularly if it is an army equipment that must operate with the other services. Joint Project 117 (JP117) which seeks to procure ground based air defence weapon systems for the Australian Army has a number of important requirements generated by the Aerospace Development Branch relating to interoperability with the Royal Australian Airforce (RAAF). As interoperability with the Navy and the C3I aspects of integration into the Australian Air

Defence picture are important, requirements may also be generated in the Maritime and C3I branches.

Defence Acquisition Organisation

The Australian Defence Acquisition Organization (DAO) (figure 6) is not part of HQADF. It acquires equipment and systems, and promotes the industry support that underpins Australia's Defence capability. It therefore manages major projects while minor projects are managed by Support Command. The baseline that generally distinguishes a major capital equipment project from a minor one is a budget of AS$20 million dollars or more.

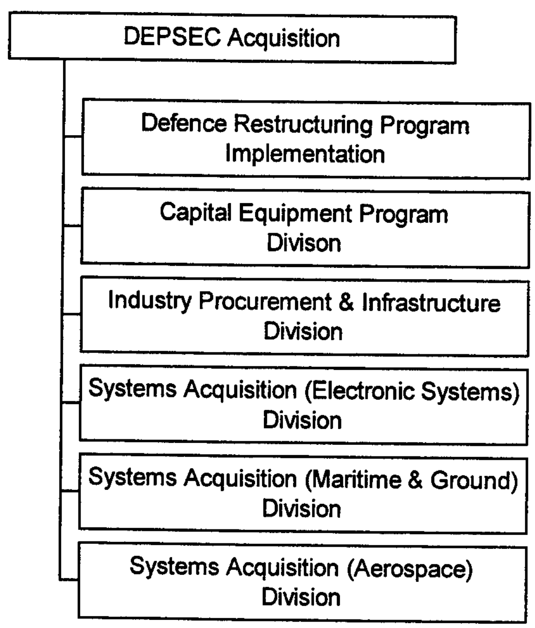

Figure 6. Defence Acquisition Organisation Organisational Chart

The DAO is made up of a number of divisions. It initially had a cell responsible for implementing government reforms arising from the Defence Restructuring Program.

The Capital Equipment Program Division provides the corporate management and acquisition finance and reporting functions. It also provides acquisition planning and advice to the Deputy Secretary on source selection. The Industry Procurement and Infrastructure Division deals with industry, contract and export policy. It deals with how industry gets involved with a particular acquisition project, and works closely with the acquisition Project Offices in the Systems Acquisition Divisions. The Systems Acquisition Divisions are organized along technological and not service lines. While most major army projects may reside within the Maritime and Ground Division, major army projects are also managed within the Electronics and Aerospace divisions. It is in the Systems Acquisition Divisions that the project management and the bulk of the system development work for major projects are traditionally done.

Support Command (figure 7) is primarily responsible for in-service management. However, as the Army's principle element within Support Command, Support Commander Army is responsible for the management of army's minor projects and is also involved in the acquisition phase.

The final organisation that is important to the development of a capability in the concept and acquisition phases is the Combined Arms Training and Development Centre (CATDC). This is an Army unit that assists in the development of capability requirements. It analyses the doctrine, equipment, organisation and training options to meet a capability requirement. It also develops and promulgates doctrine, undertakes warfighting experiments to test options, and develops and adapts training to support new capabilities.

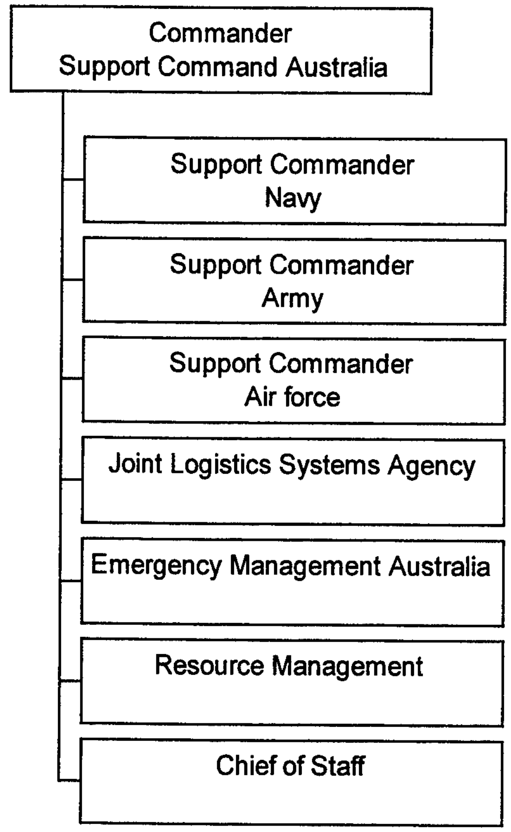

Figure 7. Support Command Organisational Chart

The Defence Materiel Cycle--Cradle to Grave

The Australian Defence Force materiel cycle is shown in figure 8. It covers the entire life cycle of a capability from the first identification of a need through to the final disposal. The cycle has four phases and could cover a period in the order of sixty to seventy years for a major weapons system. They are the concept, acquisition, in-service and disposal phases.

The materiel cycle starts in the concept phase. The complete cycle first encompasses need identification, project definition, conceptual design and project development and preliminary design. Detailed design and development is conducted

before the equipment is produced. It is then tested for acceptance by the sponsoring authority before being brought into service and supported. It is finally disposed of once it reaches its life-of-type.[2]

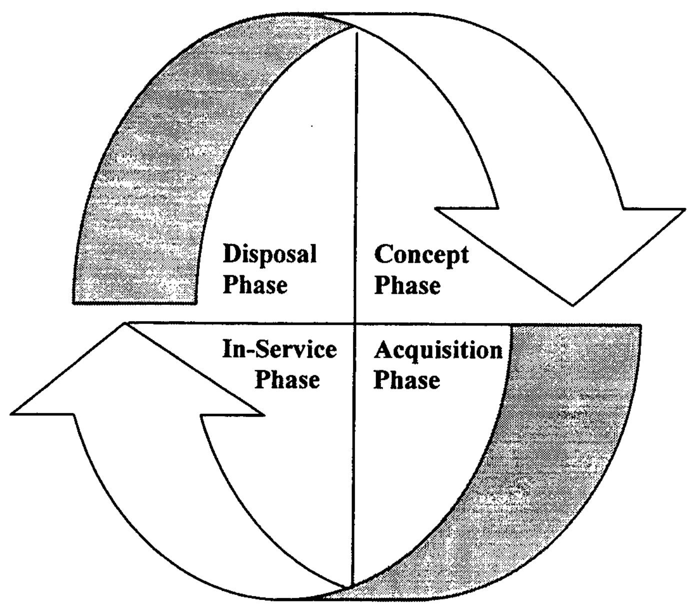

Figure 8. Defence Materiel Cycle

The materiel cycle relates to equipment solutions to capability needs. This does not however mean that the answer to a particular capability requirement will always be an equipment solution. Military capability is a combination of force structure and preparedness, while force structure is comprised of the organisation, facilities, workforce, equipment and doctrine of the ADF. The solution to a particular capability need could generate a range of options apart from any consideration of an equipment solution. Only if the non-materiel solutions are found to be unsatisfactory should a materiel solution be pursued.

This study deals with the application of a systems development methodology to materiel solutions. However, the methodology is equally applicable to non-materiel solutions although it might then be applied in a less rigorous form.

Materiel Cycle Phases

The concept phase starts with the identification of the need for a new capability through the force development process. It ends with the formal government approval to acquire the capability. The major players in this phase are the Combined Arms Training and Development Centre (CATDC), Capability Development Division (CD Div), specifically Land Development Branch; the Capability Programming and Resource Planning Division (CPRP) and to a much lesser extent the Defence Acquisition Organisation (DAO). In the case of minor projects Support Command may be involved. Close liaison between the project sponsor, the project office (if established) and other agencies, is required. Products that are developed during this phase include feasibility studies, an operational concept document and mission profile, initial cost and/or capability analysis, Front End Logistic Support Analysis (FELSA) and a logistic support concept, military options papers, options papers and issues papers. For a major project this phase is normally about one to two years, although depending on the political sensitivity or budgetary implications of the project it could take significantly longer. It is in this phase that the initial requirements for the capability are specified and cost estimates are produced as a baseline for the acquisition phase. It is therefore essential that an appropriate systems development methodology be applied during this phase to ensure that the capability definition and cost estimates are of sufficient fidelity and

quality to provide a useful baseline for the acquisition phase. Traditionally this has not been the case.

The acquisition phase starts with government approval to acquire a specified capability and ends with the capability's acceptance into service. The major player in this phase is the Defence Acquisition Organisation (DAO) for major projects and Support Command for minor projects. The respective project offices have responsibility for managing the project in this phase. Close liaison should be maintained with the project sponsor until they accept the capability into service. Other organisations that may be closely involved are the Defence Science and Technology Organisation, the Maintenance Engineering Agency, the Army Technical Engineering Agency and Support Command, for in-service support planning issues. The Industry Procurement and Infrastructure Division supports the major project offices on industry matters during acquisition. In this phase the system design activities are conducted. These include specification development, contracting, production, ILS and LSA, project management, quality assurance, test, evaluation, and acceptance. It is in this phase that the systems requirements developed in the concept phase are converted into a systems specification and most of the detailed parameters of the system are set. It is therefore essential that an appropriate systems development methodology is used during this phase.

The in-service phase starts with the transfer of responsibility for the capability from the project office to the user, and ends with the disposal of the capability. While this phase may include some refinement to the logistic support plans, mission profiles and system specifications, it is generally very costly to do so. It is therefore important that these issues are resolved as much as possible prior to the system being brought into

service. During this phase the equipment is operated by the user and sustained through logistic support. Equipment and personnel training is conducted and data are collected and analyzed as part of the continuous feedback process to increase systems effectiveness.

The disposal phase includes the reduced operation and phasing out of a capability. This may include recycling, disposal or resale. The removal of dangerous waste and materiels, and the financial and resources costs of disposal should be considered as early as possible in the materiel cycle.

Defence Procurement Process

The defence procurement process (figure 9) occurs across the entire materiel cycle. The funnel shape in figure 9[3] reflects the refinement of ideas throughout this process. The Australian Defence Headquarters is responsible for the strategic planning and capability development stages, under the Head of Strategic Policy and Plans and the Head of Capability Development respectively. Responsibility is then passed to the Deputy Secretary Acquisition whose Defence Acquisition Organization manages the acquisition of systems to meet the defined capability. Once a system has been acquired and brought into service, responsibility transfers to the user services (Navy, Army, Air Force) or Joint Service entities, for operation and through life support. This support is managed through Support Command Australia.

The stages in the procurement process are not entirely discrete however, and there are a number of overlaps. For example the DAO is almost always required to further develop the capability requirement given to it by the Capability Division before it can release a tender to industry to acquire a particular capability. Use of an effective systems

development methodology by Capability Division would reduce the amount of work that needs to be done at the transition to the acquisition stage.

The feedback loops in figure 9, indicate the requirement for continuous appraisal of, and timely reaction to, changes in strategic, operational and tactical environments, technology advances and other factors that impinge on capability.[4]

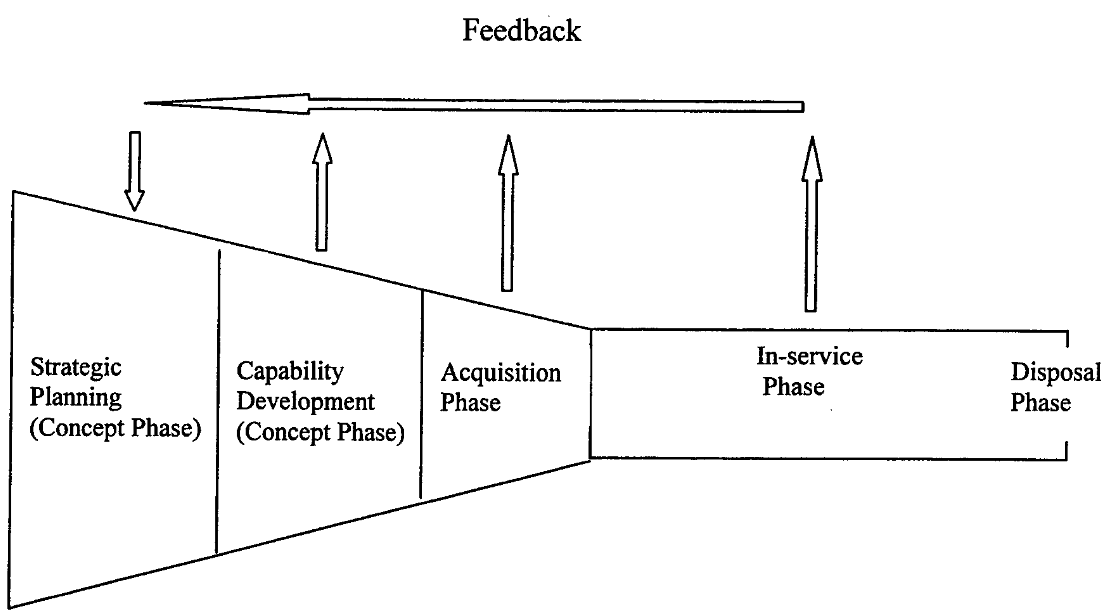

Figure 9. Defence Procurement Process

Capability Development Process

The capability development process (figure 10) has a number of key documents. The process starts with the Australian Government's strategic guidance. This provides the basis for the ADF's development planning. The major sources of strategic guidance are the Defence White Papers and strategic basis papers. The Combined Arms Training and Development Centre will develop papers on military capability options and provide

them to the Land Development Branch of the Capability Development Division who then produce Military Options Papers. It is therefore important that a systems development methodology be applied within the Combined Arms Training and Development Centre and carried through to the Land Development Branch.

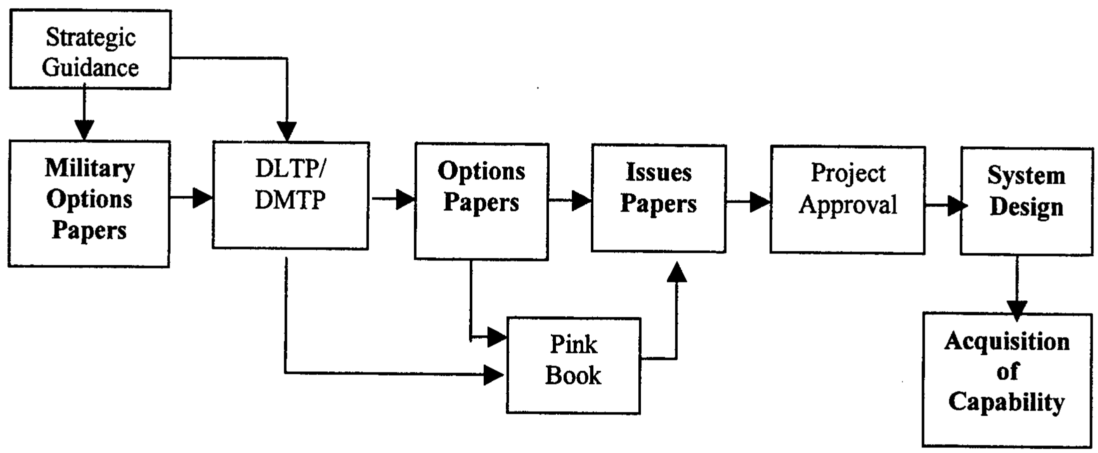

Figure 10. Key Capability Development Products in the Concept and Acquisition Phases

The Defence Long Term Plan (DLTP) which looks out 20-25years, and the Defence Medium Term Plan (DMTP) which looks out 5-10 years are developed by the Strategic Policy Planning Division. The Pink Book contains the authorized program of unapproved major capital equipment proposals. The Options Papers and Issues Papers are developed within the Capability Development Division and the Capability Programming and Resource Planning Division with occasional assistance requested from the DAO. The papers are created for committee consideration.

System Design includes all of the activities that the acquisition organisation completes to produce systems specification and Request for Tender documentation. The

Request for Tender is given to industry and tender evaluation is conducted on the offers received. The Commonwealth then acquires a complete system, which results in a capability being introduced into service.

The key committees in the capability development process are the Capability Forum and the Defence Capability Committee (DCC). The role of the Capability Forum is to make capability development decisions on issues and aspects delegated by the DCC, including less significant and less costly proposals, early definition phases of more significant proposals, and details arising from broad decisions on more significant proposals. It also gives recommendations to the DCC on the level of investment in less significant proposals for the annual program. The decisions from the Capability Forum should provide the basis of the submission seeking government approval to begin the acquisition phase. These should also provide sufficient detail on the cost/capability tradeoffs for the annual programming meeting of the DCC. [5] This means that the input to the Capability Forum should be sufficiently rigorous and properly formatted to achieve this. The application of a systems development methodology will directly affect the inputs to this committee. As a result, the members of the Capability Forum will have a key stake in the methodology's application and the nature of its outputs.

The key personnel on the Capability Forum are the chair, who is the head of the Capability Programming and Resource Planning Division and the members, who are the Head of the Capability Development Division and the First Assistant Secretary Capital Equipment Program. Invited members include the deputy chiefs of the three services and various departmental heads.

The role of the DCC is to make key decisions on capability development. It is also to recommend to the Defence Management Committee the annual program of investment to be made in capability, and it is to manage the process of getting lower level capability development decisions made. Therefore, the DCC will also dictate the form and nature of the systems development outputs.

The key personnel on the DCC are the chair, the Deputy Secretary Strategy and Intelligence (DEPSEC S&I) and the members, the Vice Chief of the Defence Force (VCDF) and the Deputy Secretary Acquisition (DEPSEC A). Invited members include the chiefs of the various services.

The Defence Source Selection Board (DSSB) endorses a major project's Equipment Acquisition Strategy (EAS) and recommends to DEPSEC-A the preferred source of supply. Because the DSSB deals with predominantly project management and contractual issues it does not become involved with the application of the systems development methodology. It is therefore not discussed further in this study.

As stated earlier, the proposed systems development methodology to be applied to the concept and acquisition phases of the materiel cycle is simply a method of applying Systems Engineering within the defence context. The relationship between Systems Engineering, ILS, LSA, and other project management methodologies adopted within Defence must therefore be understood. Chapter 4 examines each of these elements and their relationship.

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[1]Australian Department of Defence, *National Support Division--Key Result Areas and Goals*, KRA 2 Goal 3, accessed 5 Feb 99; available from http://www.defence.gov.au/NSD/f_goals.htm; Internet.

[2]Australian Department of Defence, *Major Capital Equipment Acquisition Process*, (Canberra: TLM/Kinhill, 13-17 October 1997), Session PMCO2, 4-8.

[3]Rear Admiral D. Shackleton, *Establishing the Capability Development Advisory Forum*, Discussion Paper, (Australian Defence Headquarters, Canberra ACT: Australian Defence Force, 1 Dec 98), 14.

[4]Ibid., 14, 15.

[5]Australian Department of Defence, *Project Management Education and Training Notes*, Session PMC40, 11-13.

CHAPTER 4

SYSTEMS DEVELOPMENT PROCESS

This chapter outlines a systems development methodology. This methodology is an application of an integrated approach to Systems Engineering, Integrated Logistics Support (ILS) and Logistics Support Analysis (LSA) within the defence context. To do this successfully it is necessary to understand the relationship between Systems Engineering, ILS, LSA, and other project management methodologies adopted within defence.

This chapter first examines the Systems Engineering, ILS and project management disciplines separately, and then outlines how they can be integrated within the Army to ensure that a systems approach is applied to the concept and acquisition phases of the materiel cycle.

Systems Engineering

Effective capability development is important to the warfighter because it directly affects their ability to prosecute war. If the requirements for a new system are inadequately defined the warfighter's needs will not be met. After an equipment is introduced into service they may find that it does not do what they want it to do: they cannot fight with it because it does not meet their concept of operations; they do not have the resources to support it; and it imposes an additional maintenance burden on them. If the system requirements are unnecessarily over-specified the system may increase in cost which means that they either receive less of that equipment or less of another required capability.

The Australian Department of Defence has a history of project cost and schedule overruns in developing and acquiring new capabilities, as shown in appendix A. The method of developing and acquiring capability must be improved. One discipline that may be used to achieve this is Systems Engineering.

The goal of Systems Engineering is to completely and correctly identify and validate the requirements that apply to a capability and to transform them into a description of system elements that best satisfy these requirements. It aims to achieve these goals at a cost equal to or better than budget and in a total time equal to or better than schedule.[1]

The US mandates that a Systems Engineering approach be used to translate operational needs and/or requirements into a systems solution. DOD 5000.2-R requires that the Systems Engineering process be used to establish, "a proper balance between, risk, cost, and schedule, employing a top-down iterative process of requirements analysis, functional analysis and allocation, design synthesis and verification, and system analysis and control."[2]

This is consistent with the Systems Engineering process as defined in EIA Standard IS –632, which is made up of four key activities. They are:

a. Requirements Analysis;

b. Functional Analysis/Allocation;

c. Synthesis; and

d. Systems Analysis and Control.

The Systems Engineering Process is outlined in figure 11.[3]

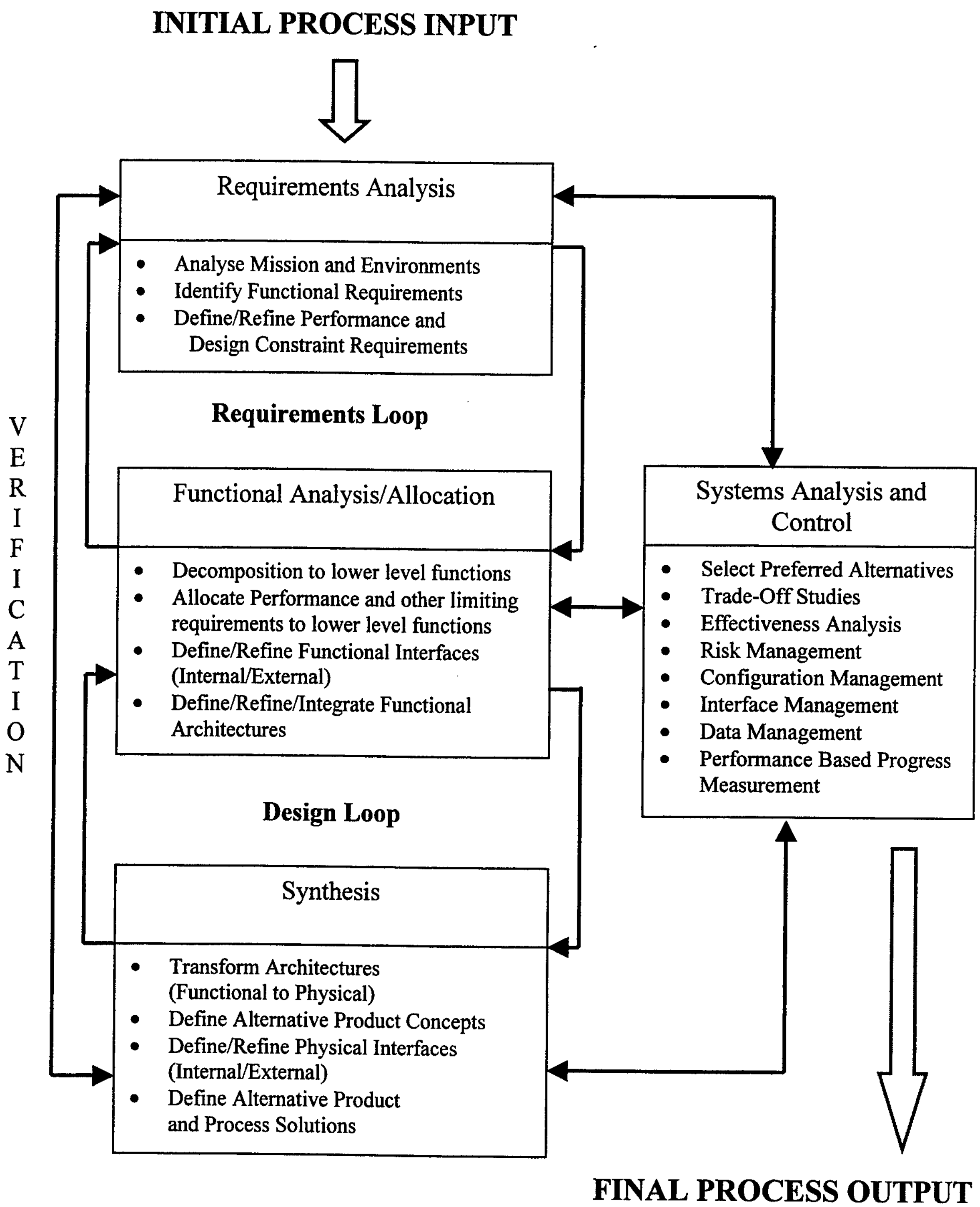

Figure 11. Systems Engineering Process

There are a number of inputs to the Systems Engineering process within defence. These include the user needs, objectives and requirements represented in strategic guidance, military option papers, and option and issue papers. Capability concept of operations and mission profiles are also incorporated as a capability becomes better defined. The constraints placed on the capability, the environment in which it must operate, and the measures of effectiveness required by various reviewing bodies must be identified and entered into the process. Other inputs include the existing technology base, any prior output data such as use studies, and financial or programming constraints. Furthermore any process that is applied within defence must account for government and internal political requirements.

The output from the process is a balanced system solution and an integrated decision database. This database would include system functional and physical architectures, specifications and baselines and decision support data. These data are developed throughout the process to an increasing level of definition. They support the decision making process of review groups and committees such as the Capabilities Forum and the Defence Capabilities Committee. Key decision support data include cost/capability options and credible life cycle cost estimates. Such data are essential for informed decision making at the committee level and significantly reduce the risk of project cost overruns in the acquisition and in-service phases of the materiel cycle. Some of the major products of Systems Engineering include:

a. System Specification,

b. Test Plans,

c. Integration Plans,

d. Trade Study Reports,

e. Configuration Management Plan,

f. Requirements Database,

g. Life Cycle Cost Reports,

h. Systems Engineering Management Plan, and

i. Interface Control Documents.

Requirements Analysis

Requirements analysis is the activity that considers customer needs, objectives, and requirements to determine the functional and physical standard for each primary system function. In the defence context, these eventually translate into a number of key documents including a system specification, which is given to industry in the acquisition phase. Requirements analysis is conducted within the context of the capability's mission and operating environment, its use and any predetermined system characteristics. Prior analyses are reviewed and updated and mission/operational and environmental definitions are refined. The operating environment is examined to determine the context within which the system is to operate, and the boundary between the system and the outside environment. A traceable top down hierarchy of requirements is produced during this stage. Figure 12 shows an example of a top down requirements hierarchy.

Requirements may include physical, interface, environmental, resource, functional or performance characteristics. Physical requirements relate to the physical properties of the system. Interface and environmental requirements deal with how the system interacts with the outside environment. Resource requirements deal with what resources the system consumes, for example, ammunition. Functional requirements state

what the system is to do and performance requirements state how well the system is to do it.

In accordance with EIA Standard IS-632, the requirements validation process establishes an upward and downward traceability of requirements that result from the inputs to the Systems Engineering process. This ensures that each lower level requirement comes from a higher level one. It is essential that requirements traceability is maintained as the requirements gain greater definition whilst in the concept and acquisition phases of the materiel cycle.

This requirements hierarchy not only provides a baseline against which the functional requirements of the system are developed but provides visibility and justification for each requirement listed. This is particularly important when the Organisations managing the development of a capability appear before review groups and committees. The impact of removing and changing requirements can be clearly demonstrated and tracked. For example, if a committee wished to remove requirement 2.2.2 (figure 12), then it could be clearly demonstrated that the capability would no longer be able to meet requirement 2.2 and its ability to meet requirement 2.0 would be significantly affected. It would also highlight that requirements 2.2.2.1, 2.2.2.2 and their lower level requirements would no longer be needed, thus avoiding producing a capability against invalid and unnecessary requirements.

The benefits of requirements analysis are that it:

a. assists in refining customer objectives and requirements;

b. defines the problem by identifying the objectives for the capability and refines them into requirements;

c. identifies and defines the constraints on possible solutions (for example, manpower ceilings, budgetary limitations, environmental considerations)

d. defines the functional and performance requirements based on the required measures of effectiveness. If measures of effectiveness have not been provided in sufficient detail, then they are developed during this stage.[4]

Functional Analysis/Allocation.

Functional analysis and/or allocation is the activity that determines the detailed functions the capability must perform. It defines and integrates a functional architecture to the level of detail needed to support the production of solutions in the synthesis stage of the Systems Engineering process. Functional analysis and/or allocation is a method for analyzing performance requirements and decomposing them into discrete tasks or activities. This functional decomposition is conducted iteratively both to develop lower level functions based on higher level functional requirements and to ensure that performance requirements and design constraints flow down.[5]

A function is "a characteristic action to be accomplished by one of the system elements of hardware, software, facilities, personnel data, or any combination thereof."[6] The decomposition of a system can be viewed as a top-down approach to problem solving. It results in a hierarchical tree structure, which progressively divides and allocates requirements until the lowest level function that meets a definable requirement is reached.

The opposite approach is a bottom-up method that is easier to apply to situations where a number of existing components, with well-defined capabilities are combined to meet the system objectives. Due to budget and schedule constraints, this approach more

closely represents the real world. However, due to interface and interoperability issues that exist even with nondevelopmental projects, this approach may be difficult to implement. In practice, a combination of both the top-down and bottom-up approaches is used.

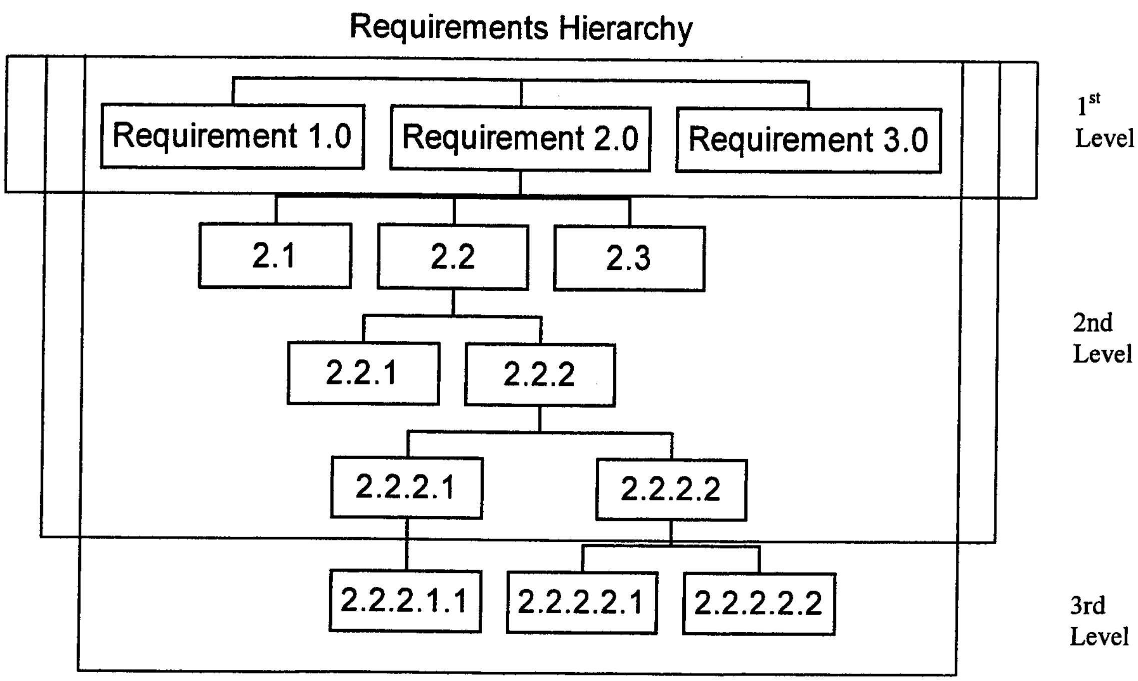

Figure 12. Requirements Hierarchy

Functional analysis is conducted iteratively and in parallel with requirements analysis so that the elements of the requirements hierarchy relate directly to the developing functional requirements, and higher level requirements are met (figure 13). This maintains consistency between requirements and design. It is performed iteratively with the synthesis stage of the Systems Engineering process to define and refine workable solution alternatives that meet the stated requirements.

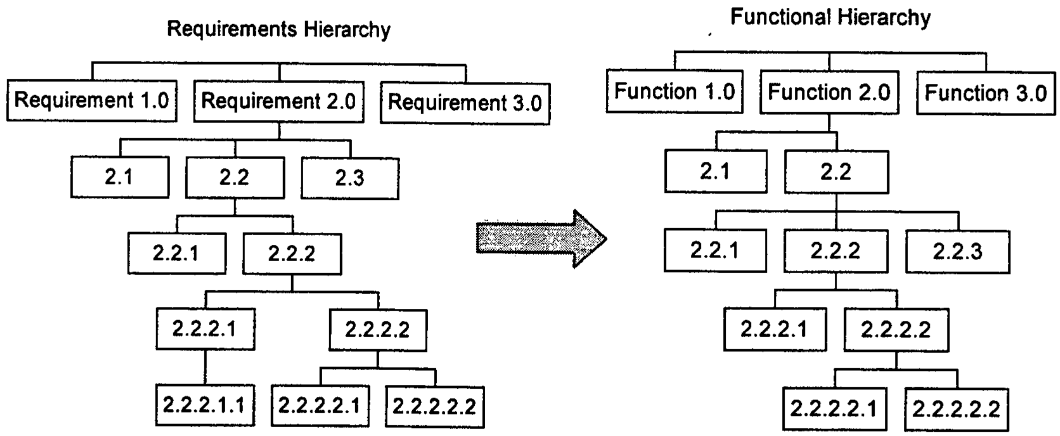

Figure 13. Requirements and Functional Hierarchies

The relationship between requirements and functions is not necessarily one to one. Each requirement may generate a number of different required functions, for example there may be a requirement for a communications control system that is capable of switching both local and transit traffic. Some derived functions for part of the system could be "send signal" and "receive signal."

A functional architecture (figure 14) is developed from a functional hierarchy (figure 13). A functional architecture views the system as a network of interfacing functions. It shows the relationship between the various functions, the inputs and outputs and the sequence of operation of the functions to achieve a particular result.

Synthesis

The Synthesis activity produces solutions for each set of functional and performance requirements in the functional architecture. These solutions are called physical architectures. A physical architecture is an arrangement of the hardware, software, facilities, personnel and other components that make up a system (figure 15).[7] It shows the relationship between the physical components of the system and the major

functional, performance and other requirements of each component of the system.[8] As a rule the army will not get involved in designing and building its own equipment and prefers "nondevelopmental" items. Therefore it is not intended that these physical architecture options be built by defence. However, they provide the basis for cost/capability analysis and logistics modeling.

Major committees generally do not have the time or inclination to examine abstract requirements or functional architectures in detail and prefer their data in a simple and easily understandable form. As a result, the physical architecture options are likely to be among the key products that are presented to these reviewing bodies.

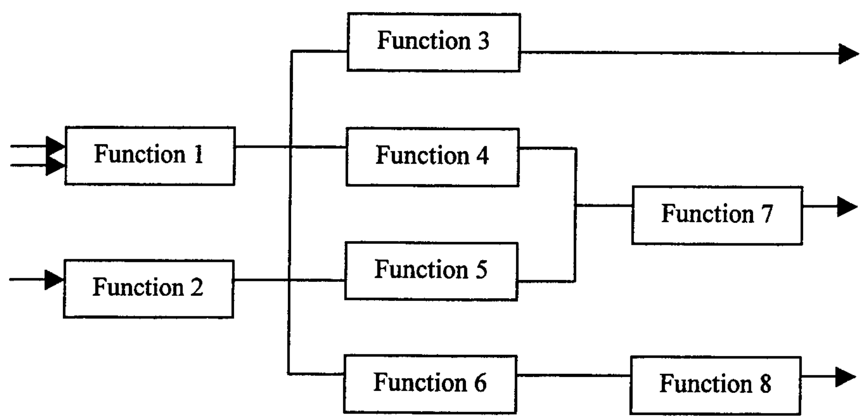

Figure 14. Functional Architecture

Synthesis is conducted interactively with functional analysis and/or allocation and requirements analysis. The outputs must describe the complete system, including internal and external interfaces and relationships.

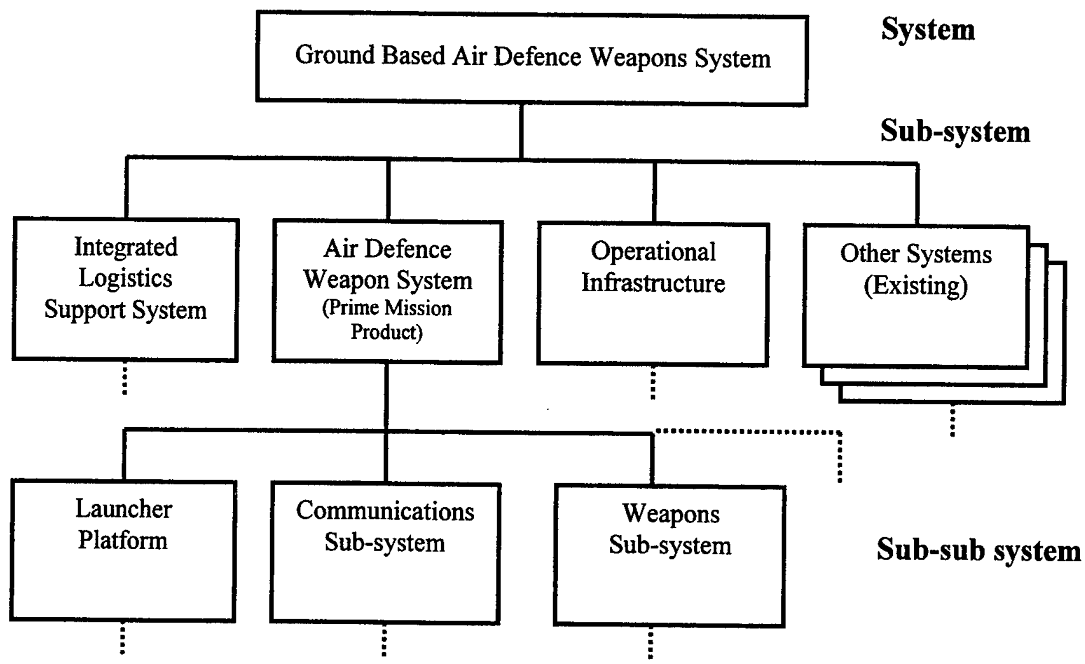

Figure 15. Physical Architecture Example

The Synthesis activity:

a. determines whether the functional and performance requirements are complete and derives additional requirements;

b. defines sets of functions and allocates them to parts of the system being specified;

c. defines and integrates any internal or external physical interfaces;

d. identifies and analyses critical parameters;

e. defines alternatives in terms of hardware, software, people, and processes;

f. defines system, subsystem, and system element solutions to a level of definition required for the production of a functional system specification;

g. translates the architecture selected from the cost/capability analysis into a specification tree, specifications, configuration baselines and a work breakdown structure, as required.[9]

Figure 16 shows the process flow for the Synthesis activity. It shows the relationship between functional hierarchies, functional architectures and physical architectures.

Synthesis Activity--Application of Design. The synthesis activity designs solutions for each set of functional and physical requirements. The design activity detailed in EIA Standard IS-632 must be significantly tailored for application to the Army. The design activity as it will normally be applied within the Army relates primarily to the design and development tendering of documentation. The primary document produced is the system specification. As applied to the Army, the design activity develops:

a. the information for establishing and updating applicable functional, allocated, and product baselines as required;

b. system, lower-level item, process, and materiel specifications including commercial item requirements;

c. interface control requirements;

d. life cycle resource requirements; and

e. procedural handbooks and instructional materiel requirements.

Synthesis Activity--Application within Defence. It is important to realize the manner in which the synthesis activity is to be applied within defence. The synthesis activity as detailed in EIA Standard IS-632 is described in terms applicable for its use by

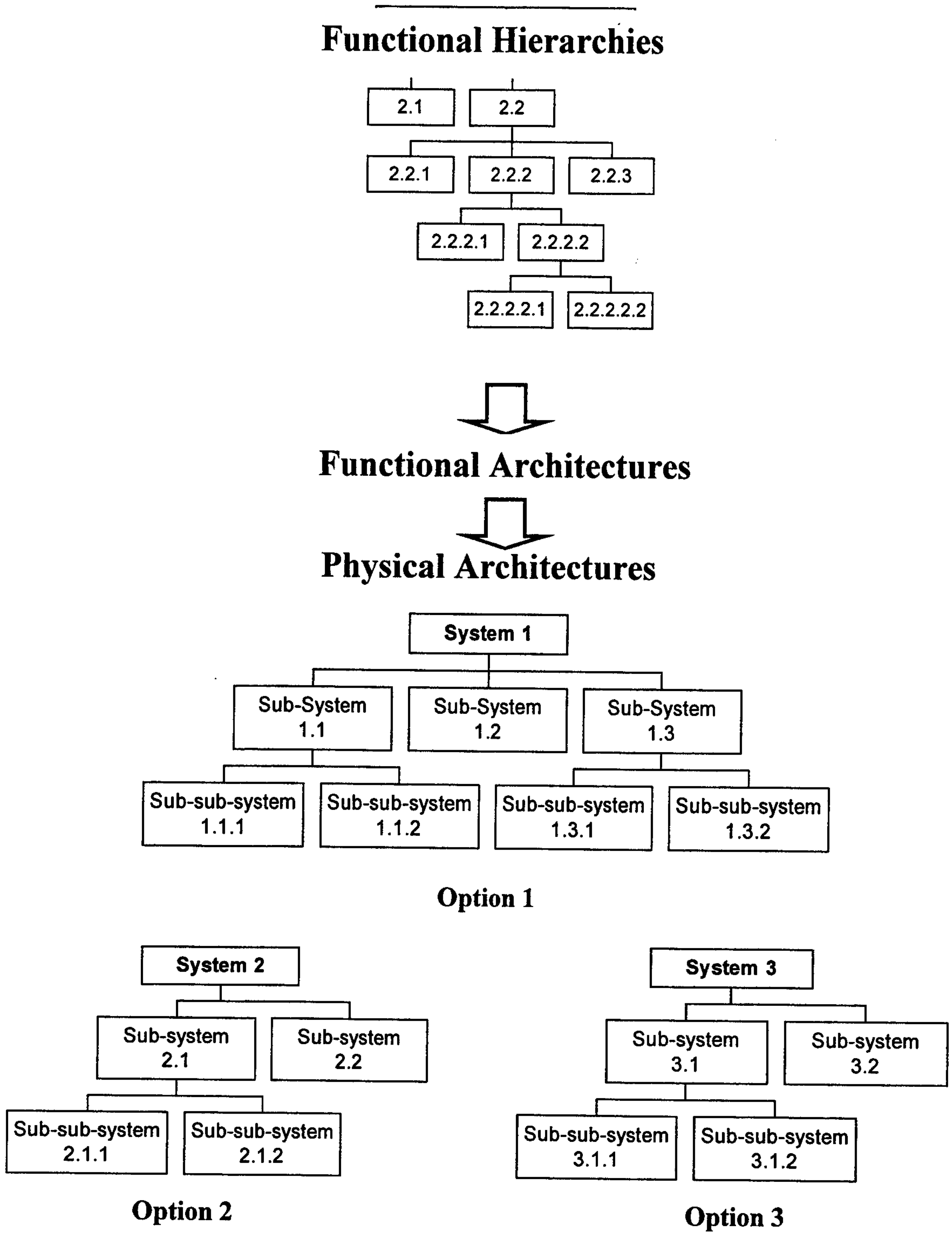

Figure 16. Synthesis Process

organisations conducting new systems development, upgrades, modifications and the technical efforts required in preparation to responses to solicitations. However for the Army, in the concept and acquisition phases of the materiel cycle, these tasks are the responsibility of industry. This does not make the synthesis activity any less relevant to defence. The activity must be tailored to meet defence's needs.

In defence's case, the synthesis activity is conducted to assist in the production of generic physical architecture options that are used in cost and/or capability analyses and act as benchmarks for LSA activities. The synthesis activity also directly supports requirements analysis and the determination and allocation of functional and performance requirements necessary for the production of a complete systems specification.

Where the likely physical solution is a nondevelopmental item, the synthesis activity ensures that the characteristics of the nondevelopmental item fit within the characteristics defined by system requirements. It is not often the case that a solution will be entirely nondevelopmental and require no integration. It is more likely that the possible solutions will be assembled from a set of elements, of which one or more is a non-developmental item. In this case, the synthesis activity ensures that the characteristics of the nondevelopmental item fit within both the system characteristics defined for that specific element and the overall related systems requirements.

Materiel Solution Determination. There is a danger that the physical architecture options may be used inappropriately. The Systems Engineering process assists defence in better defining its requirements. This may narrow the field of materiel solutions, thereby saving industry and government time and money. However committees should not use the physical architecture options as the basis for predetermining materiel

solutions. It should remain the role of industry to present materiel solutions to the government as part of a tendering process against a properly detailed system specification. It is against these responses that final materiel solution decisions should be made. It is important that industry be allowed to present their solutions to defence's requirements without a specific materiel solution having already been predetermined.

Physical architecture options are used throughout the Systems Engineering process to provide clarity, visibility, and definition as the system is developed. They establish the feasibility of physically realizing the functional architecture and provide an input to effectiveness analysis. This analysis results in the selection of at least one physical architecture to be carried forward for further detailed design. Physical architecture options are not to be used for prematurely determining specific materiel solutions.

Systems Analysis and Control

The systems analysis and control activity measures progress, evaluates alternatives, selects preferred alternatives, and documents data and decisions. Systems analyses are conducted, including trade-off studies and effectiveness, cost/capability and design analyses. Control mechanisms include the use of risk, configuration, interface, and data management, and the application of performance based measures specific to a particular capability.

Systems analysis and control aims to ensure that:

a. decisions on solution alternatives are made on the basis of the entire system. This includes the impact on system effectiveness, life cycle cost and resource requirements, risk and user requirements;

b. traceability is maintained throughout the whole process;

c. technical, logistic and supporting disciplines are integrated into the Systems Engineering effort;

d. the impact of user requirements is examined for validity, consistency, desirability and attainability with respect to available resources, life-cycle costs, risks, regulations, and other identified constraints and limitations. The level of existing and emerging technology must be examined to ensure that the developing requirements are reasonable and achievable within the time, resource and risk constraints of the project;

e. schedules for the development and delivery of products and processes are mutually supportive; and

f. the total impact to defence of changes to the technical requirements with respect to cost, schedule, performance, and risk are defined and reported and their effects determined.[10]

Verification

The verification activity (figure 11) progressively checks that the product and process designs satisfy their requirements. Since in the Army's case the major product being designed will usually be a systems specification rather than a hardware system, the verification process ensures that the specifications are actually required.

Plans

In order to implement the Systems Engineering process a Systems Engineering Management Plan (SEMP) is required. A SEMP represents the tailoring of a Systems Engineering Standard, such as EIA Standard IS-632 to meet that organisation's needs.

The SEMP is updated regularly and describes the Systems Engineering process and the organisation's plan to execute that process. It provides a focus for the integration of engineering specialties. The SEMP becomes a sub plan of a Project Management and Acquisition Plan (PMAP). This is the central document that outlines how a project is to be managed. The PMAP details how the project management, Systems Engineering and logistics requirements for a project are to be completed.

Logistic Support

The DI(G)ADMIN 05-1 mandates that logistic support issues be considered as part of the planning and preparation for a capability seeking project approval. The *Capital Equipment Procurement Manual* (CEPMAN 1) also requires that logistics issues be considered as part of the project planning process. A systems approach to the development of a capability must consider all of the logistics issues necessary to assure that an equipment system is supported effectively and economically throughout its programmed life. To achieve this, the Australian Defence Force's *Logistic Support Manual* (LOGMAN) provides policy and procedural guidance to assist in adopting a unified approach to logistic support.

Logistic support aims to:

a. achieve preparedness objectives at minimum life cycle cost;

b. provide an integrated and systems approach to logistic support aspects using the management tools of ILS (ILS), Logistic Support Analysis (LSA), Reliability and Maintainability (RAM) and Life Cycle Costing (LCC) throughout the life cycle; and

c. create, store, retrieve, distribute and use, data and information in digital format to aid management decision making.[11]

Integrated Logistics Support

The ILS is the basis for the development of supportability for an equipment system for its entire service life whilst minimizing life cycle costs. The ILS is a total support concept. The elements of ILS include all of the considerations necessary to ensure adequate and economic support is provided for an equipment system. The core elements of ILS are:

a. maintenance planning;

b. engineering support;

c. supply support;

d. support and test equipment;

e. technical data;

f. manpower and personnel;

g. training and training support;

h. facilities;

i. packaging, handling, storage and transportation; and

j. computing support.

These elements are to be considered to varying degrees and additional elements added depending on the equipment systems under consideration for each capability.

It is Defence policy that: "The principles of ILS shall be applied to all projects including software, collaborative and non-developmental projects. The ILS is to be applied to non-developmental projects during the concept and acquisition phases in

sufficient depth to ensure that selection is based on total life-cycle costs and that support implications are clearly linked to the decision taken."[12]

The objectives of ILS are to influence the design of a capability to ensure that it has a desired level of availability whilst minimizing support requirements and life-cycle costs. It also aims to ensure that all of the appropriate ILS elements are planned, assessed and implemented in parallel with the development, acquisition, operation and disposal of the system. The application of ILS should prepare users and support elements to operate and support new equipment. It also should provide procedures to acquire, integrate and dispose of the system. The ILS aims to ensure that supportability and life-cycle costing issues are given adequate consideration in the requirements determination and acquisition processes.[13]

During the concept phase, ILS objectives are concerned with alternative solutions to satisfy the operational requirements. The aim is to design for support. During the acquisition phase ILS is predominantly directed towards the development of maintenance schedules, spares assessing and procurement, training development, supportability and test equipment and documentation.

Reliability, Availability and Maintainability

Reliability, Availability, and Maintainability (RAM) requirements must be specified early in the concept phase. They provide the engineering basis for all subsequent logistics activities. Without their inclusion in the initial requirements definition, there is no basis provided for subsequent logistics planning. During the acquisition phase reliability and maintainability predictions and allocations are conducted to ensure that the design meets the supportability requirements. Reliability and

maintainability demonstrations may be conducted towards the end of the physical design process as appropriate for the capability being acquired.

Life Cycle Costing

One of the first tasks to be completed in the concept phase is to produce a broad estimate of the financial cost of the required capability. This estimate is updated as the capability takes on a greater level of definition. In the concept phase this estimate is refined into Pink Book figures and is used to support the detailed design, development and production process. It is important that these figures are accurate as they define the limits for spending on a capability in the acquisition phase.

In the acquisition phase the Pink Book estimates are again refined. Life cycle costs, rather than just acquisition costs, should be used in the tender evaluation process as the basis for comparison between tenderers.

Studies conducted by the US DOD[14] of Defence Projects over the past twenty years showed that if a change to increase supportability were made during the design process and cost $1.00, that same change made during production would cost $100,000. If the change were not made until after introduction, the cost would escalate to $1,000,000.

Whilst exact figures vary from different sources, it is generally held that by the end of the concept phase, 70 percent of the decisions affecting life cycle costs have been made. Approximately 85 percent of the decisions have been made once the system is fully defined in the acquisition phase and by the time a contract for a capability is signed, 90 percent of through-life costs have been established (figure 17).[15]

The Australian Logistic Support Manual is less conservative and states that a higher percentage of decisions occur even earlier for developmental projects. It states that, "for a typical full developmental program, 90 percent of the decisions affecting Life Cycle Costs (LCC) would have been made at the end of the concept phase and only 10 percent of the cost reduction opportunities would be available after this phase."[16] This highlights the need to get requirements determination and system definition right as early as possible from both the logistics and the technical side.

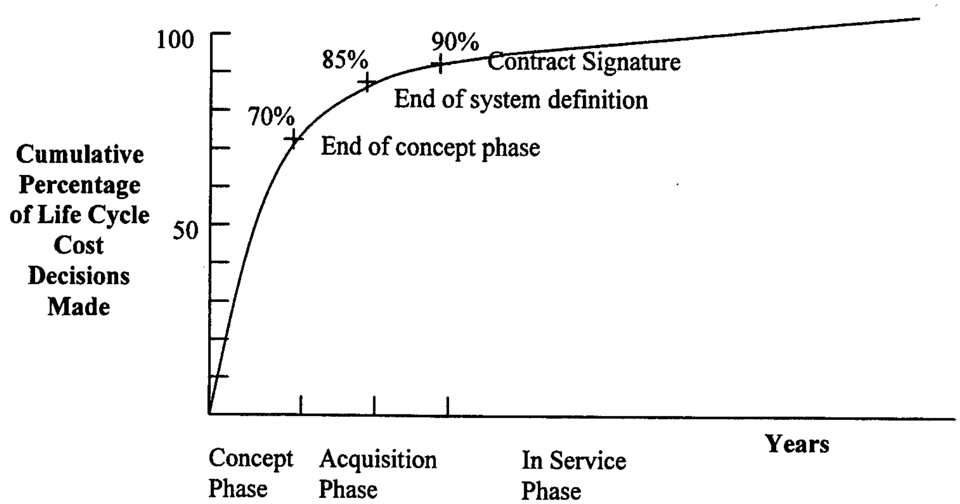

Figure 17. Life Cycle Cost Definition

If sufficient effort is not given to adequately developing the capability requirements in the concept phase then defence will ultimately procure a capability with a higher than necessary life-cycle cost. The basis for accurate cost estimation will also be inadequate. Basing cost estimates on an inadequately defined capability requirement significantly increases the risk that project cost overruns will occur in the acquisition and

in-service phases. Cost overruns reduce defence's ability to manage its limited budget and achieve the introduction into service of the full range of required capabilities.

Major ILS Products

In the concept phase a logistics support concept must be developed as early as possible in the process so that supportability is considered in the system design when changes are easy and inexpensive to implement. The first product of the logistics support concept is the maintenance concept. It is from this product that all other ILS elements take their lead.

Consideration of ILS elements, LSA strategy and ILS management should be included in the military options papers, options papers and issues papers. It is important that these identify support concepts, objectives and areas of risk early in the concept phase. Of particular importance is the need to make an early estimate of the life-cycle costs of the options to be considered. If the cost of logistics support is not considered until the acquisition phase, it could have a detrimental effect on the operational aspects of the capability to be procured.[17]

In the acquisition phase the first iteration of an ILS Plan (ILSP) must be developed as early as possible. The ILSP is the business plan for logistics. The Project Management and Acquisition Plan (PMAP) is the business plan for the project which controls the management of ILS, Systems Engineering and project management, activities for the project. The ILSP is a subset of the PMAP.

A logistics Statement of Requirement is also written at this stage. This is included in tender documentation for a required capability and is converted into a

logistics Statement of Work on the award of a contract. A suite of other supporting logistics products is developed during this phase.[18]

Logistic Support Analysis

The ILS is underpinned by LSA. The LSA is detailed in MIL-STD-1388-1A and *LOGMAN*. It is an analytical tool that provides a methodology to integrate ILS and provides a logical progression of events for ILS application. It is a structured approach to evaluating the logistic support characteristics of a design and for assessing in-service support requirements. Conducting LSA ensures that each of the elements of ILS are considered in the system design.

LSA applies to all phase of a capability's life cycle. It is an iterative process that conducts studies, analyses and trade-offs, and tests and trials with the aims of successfully refining an equipment system's design and optimizing its support requirements.

LSA must be tailored to suit the individual characteristics of each capability development project. No one model for the application of LSA will apply to all projects. However, this study will provide a generic model for the application of LSA in the concept and acquisition phases. The purpose of this is to indicate the timing and integration of logistics issues into the development and acquisition process rather than to mandate the standardized use of specific LSA Tasks.

Major LSA Tasks

The conduct of LSA breaks down into a series of tasks. The LSA tasks do not represent additional requirements that increase project schedules, management or

tendering costs. They are the most effective way of meeting the logistics support requirements already prescribed in Defence policies.

The LSA tasks for a project in *LOGMAN* and MIL-STD-1388-1A are:

a. Task Section 100--LSA Planning and Control;

b. Task Section 200--Mission Support Systems and Definition;

c. Task Section 300--Preparation and Evaluation;

d. Task Section 400--Determination of Logistic Support Requirements; and

e. Task Section 500--Supportability Assessment.

A detailed list of LSA tasks and sub-tasks is contained in appendix B. Not all tasks need to be applied to all projects. The use of appropriate tasks should be tailored to each project.

The objective of LSA in the concept phase is to allow logistics issues to influence the way a system is to be supported. The LSA strategy and supportability related tasks such Front End Logistic Support Analysis are conducted in this phase. Although, historically the Use Study has been written in the acquisition phase, it should be written in the concept phase. This task will go through a number of iterations and will take on an increasing level of definition throughout the phase. In the initial stages, the results of these LSA tasks will have little definition. However, it is important that they each be considered as early as possible to ensure that logistics issues are adequately addressed in the system design.

In the acquisition phase the LSA Plan is written and the LSA Tasks relevant to the project are progressed. Completion of the LSA tasks results in a suite of integrated

logistics studies and ILS data. These ILS data are in the form of a relational database known as the LSA Record or LSAR.

The completion of LSA tasks occurs through a series of iterations throughout the materiel cycle. For example, the production of an LSA strategy should be started in the early stages of the concept phase. It must be continually refined and will not be completed until the system definition stage in the acquisition phase. A recommended implementation for the primary LSA sub-tasks in the concept, acquisition and in-service phases is shown in figure 18.[19] This is based on guidance from *LOGMAN*.[20]

Project Management

Another discipline critical to the systematic development of a capability in the concept and acquisition phases is Project Management. It is necessary to examine the relationship of Project Management to Systems Engineering and ILS in order to understand its role in a systems development methodology.

Project Management, Systems Engineering and ILS are disciplines that when applied to the development of a capability, should assist the capability to be brought into service on time, within budget, and with an agreed level of quality. Their relationship is shown in figure 19.

The balance between these three disciplines varies throughout the concept and acquisition phases. For example, the application of formal project management techniques does not normally occur until a project team within the Defence Acquisition Organisation is formed just prior to the commencement of the acquisition phase. Systems engineering and ILS are also applied at increasing levels of definition throughout the concept and acquisition phases, with the initial application being requirements definition

	Concept Phase		Acquisition Phase		In-Service Phase	
LSA TASK SECTIONS AND TASKS	Military Options Paper	Options/ Issues Papers	EAS PDS	FSD	Production Deployment In-service	Design Changes
<u>TASK 100</u> <u>LSA PLANNING AND CONTROL</u>						
Early LSA Strategy (101)	X	X	X			
LSA Plan (102)		X	X	X	X	X
LSA & Design Reviews (103)		X	X	X	X	X
<u>TASK 200</u> <u>MISSION AND SUPPORT SYSTEMS DEFINITION</u>						
Use Study (201)	X	X	X	X		
System Standardisation (202)		X	X	X		X
Comparative Analysis (203)	X	X	X	X		
Technological Opportunities (204)		X	X			
Supportability Factors (205)		X	X	X		X
<u>TASK 300</u> <u>PREPARATION AND EVALUATION OF ALTERNATIVES</u>						
Functional Requirements ID (301)		X	X	X		X
Support System Alternatives (302)		X	X	X		
Eval of alternatives & trade-offs (303)		X	X	X		X
<u>TASK 400</u> <u>DETERMINATION OF LOGISTIC SUPPORT RESOURCE REQUIREMENTS</u>						
Task Analysis (401)			X	X		X
Early Fielding Analysis (402)				X		X
Post Production Support (403)					X	X
<u>TASK 500</u> <u>SUPPORTABILITY ASSESSMENT</u>						
Supportability Assessment (501) (Test, Evaluation and Verification)		X	X	X	X	X

Figure 18. LSA Tasks and sub-tasks by product and phase.

Legend:
EAS – Equipment Acquisition Strategy
PDS – Project Definition Study
FSD – Full Scale Development

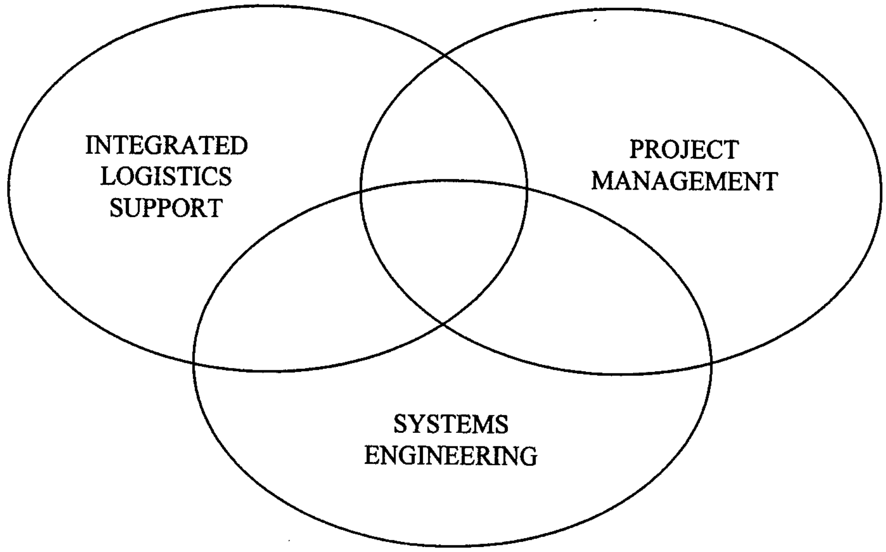

Figure 19. Project Management, Systems Engineering and Integrated Logistics Support Relationship

and logistics use studies. The integration of Systems Engineering and ILS produces a complete methodology for the systematic development of a capability.

There are two different ways of viewing the relationship between ILS and Systems Engineering. The first sees ILS as a function included within Systems Engineering which only becomes a separate function after the system design becomes mature. The second views ILS and Systems Engineering as separate functions that exist within a project and exchange data and guidance. This approach represents the current way most projects are organized and represents Army's current position.

This integrated application of Systems Engineering and ILS produces a systems development methodology that could be adopted by the Australian Army to ensure that a systems approach is applied to the concept and acquisition phases of the materiel cycle. The application of project management techniques to this systems approach should result in the capability being brought into service within budget, having considered all of the

aspects affecting the system. It should have an optimal life cycle performance, satisfy customer needs and meet the constraints on the system.

The relationship between the attributes of Systems Engineering, ILS and project management are shown in figure 20.[21]

Figure 20 shows important overlaps between the three key disciplines of Systems Engineering, ILS and project management. Those attributes shown as being unique to project management are the more commercial aspects of the task conducted within the Defence Acquisition Organization. Whilst the three disciplines are clearly related, Systems Engineering and ILS are primarily concerned with managing the capability and project management is concerned with managing the project. Therefore any methodology that aims to ensure that a systems approach is applied to the concept and acquisition phases of the materiel cycle should integrate Systems Engineering and the elements of ILS. This methodology should then be implemented using project management techniques.

In further defining the relationship between Systems Engineering and the elements of ILS it should be remembered that LSA is the structured methodology that integrates and applies the various elements of ILS across the materiel cycle. Its relationship to Systems Engineering is outlined in MIL-STD-1388-1A and *LOGMAN*. These references state its application as being, "part of the Systems Engineering and design process, to assist in complying with the supportability and other Integrated Logistics Support (ILS) objectives through the use of an iterative process of definition, synthesis, trade-off, test and evaluation."[22] This means that to carry out ILS you must

complete LSA tasks. Therefore, in order to integrate Systems Engineering and ILS you must integrate Systems Engineering and LSA tasks.

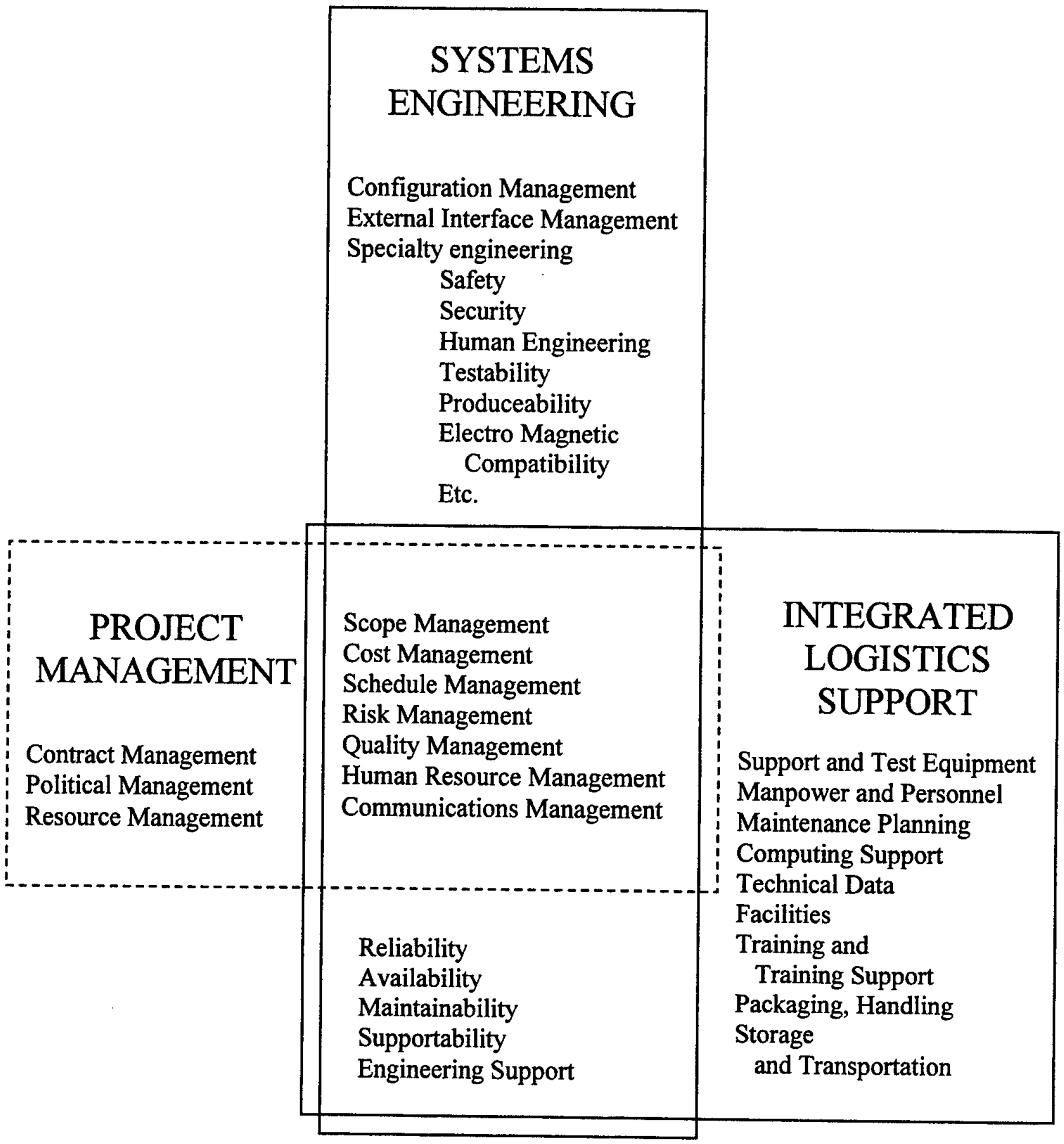

Figure 20. Relationship between the attributes of the Systems Engineering, Integrated Logistics Support and Project Management

It is now possible to examine how Systems Engineering and LSA can be integrated to produce a systems development methodology for the Australian Army which can be applied in the concept and acquisition phases of the materiel cycle.

Systems Development Methodology

Figure 10 outlined the key capability development products in the concept and acquisition phase. Figure 11 outlined the Systems Engineering process and figure 18 outlined which LSA tasks are to be conducted at various stages in the capability development process. The integration of these areas produces a systems development methodology for the Australian Army that can be applied in the concept and acquisition phases of the materiel cycle. This methodology will be presented in terms of the development of key capability development documentation.

The first key document to be produced is the Military Options Paper. The Land Development Branch within Capability Development Division has prime responsibility for this. They receive input from the Combined Arms Training and Development Centre. The Military Options Paper should be developed in accordance with figure 21.

The second key document is the Options Paper. The Capability Development Division has prime responsibility for this and is assisted by the Capability Programming and Resource Planning Division. It should be developed in accordance with figure 22.

The third key document is the Issues Paper. The Capability Development Division also has prime responsibility for this and is assisted by the Capability Programming and Resource Planning Division. It should be developed in accordance with figure 23.

The process described as "System Design" occurs in the acquisition phase. It is the prime responsibility of the Defence Acquisition Organisation. It should be developed in accordance with figure 24.

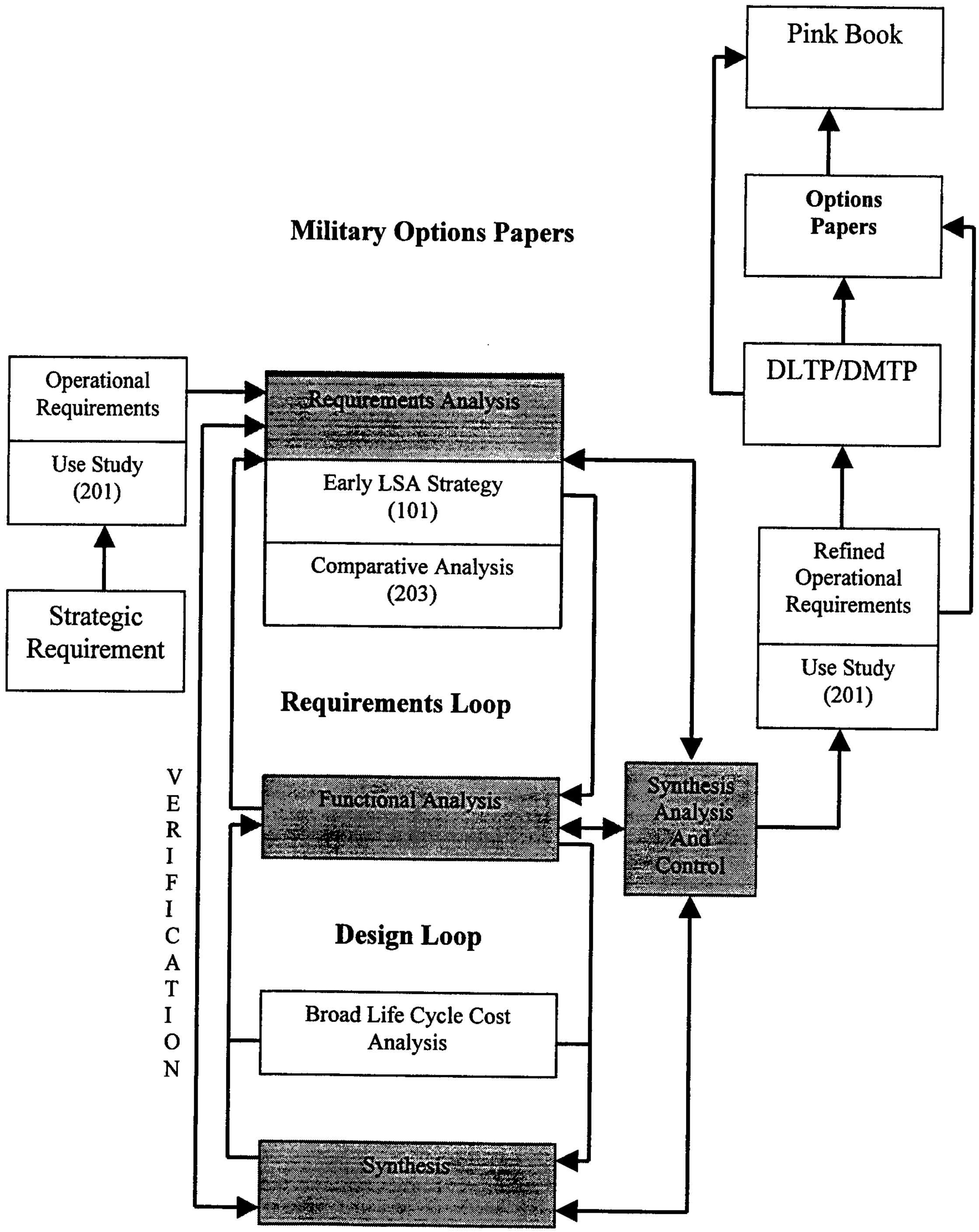

Figure 21. Systems Development Methodology--Military Options Paper

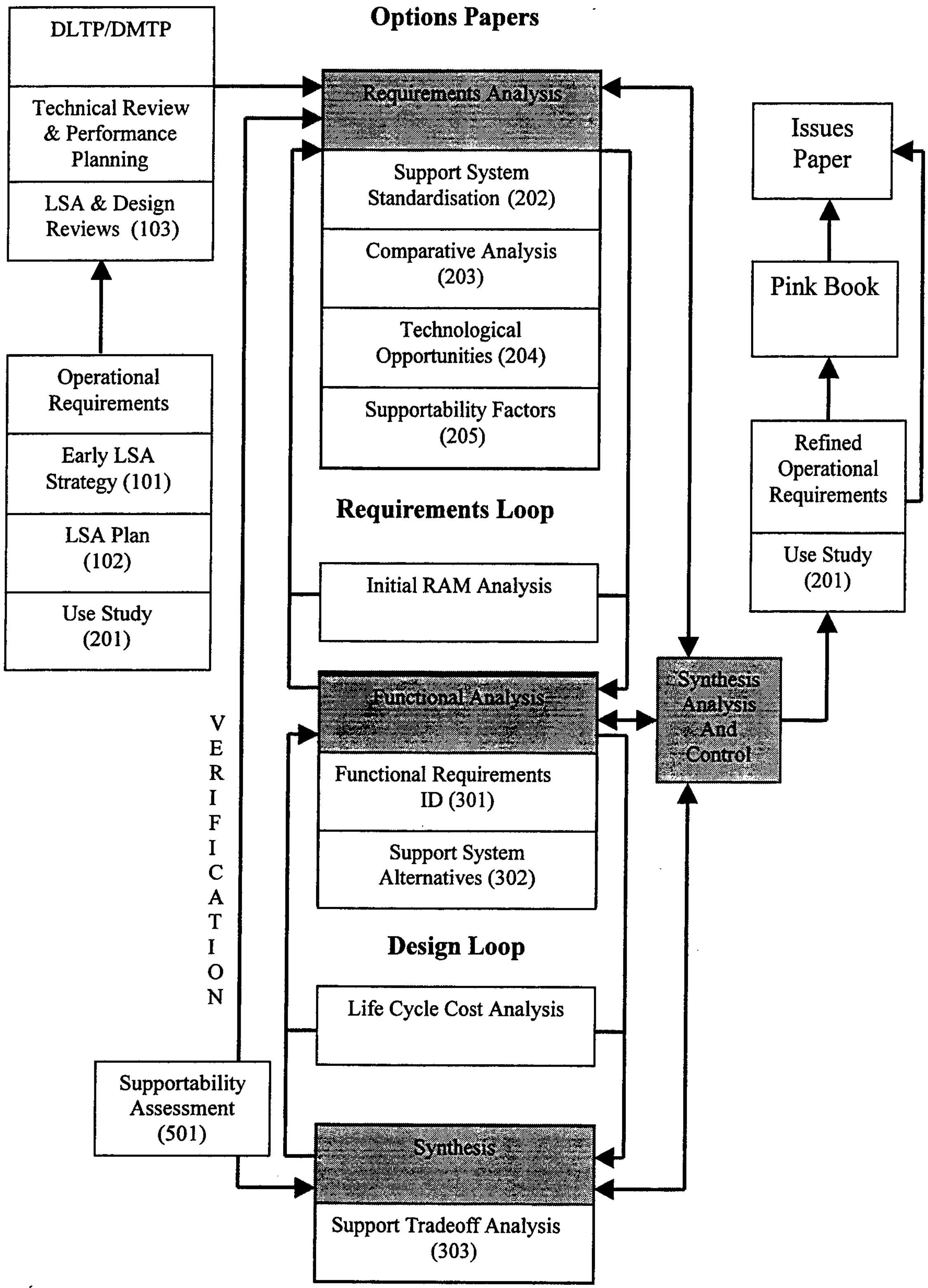

Figure 22. Systems Development Methodology--Options Paper

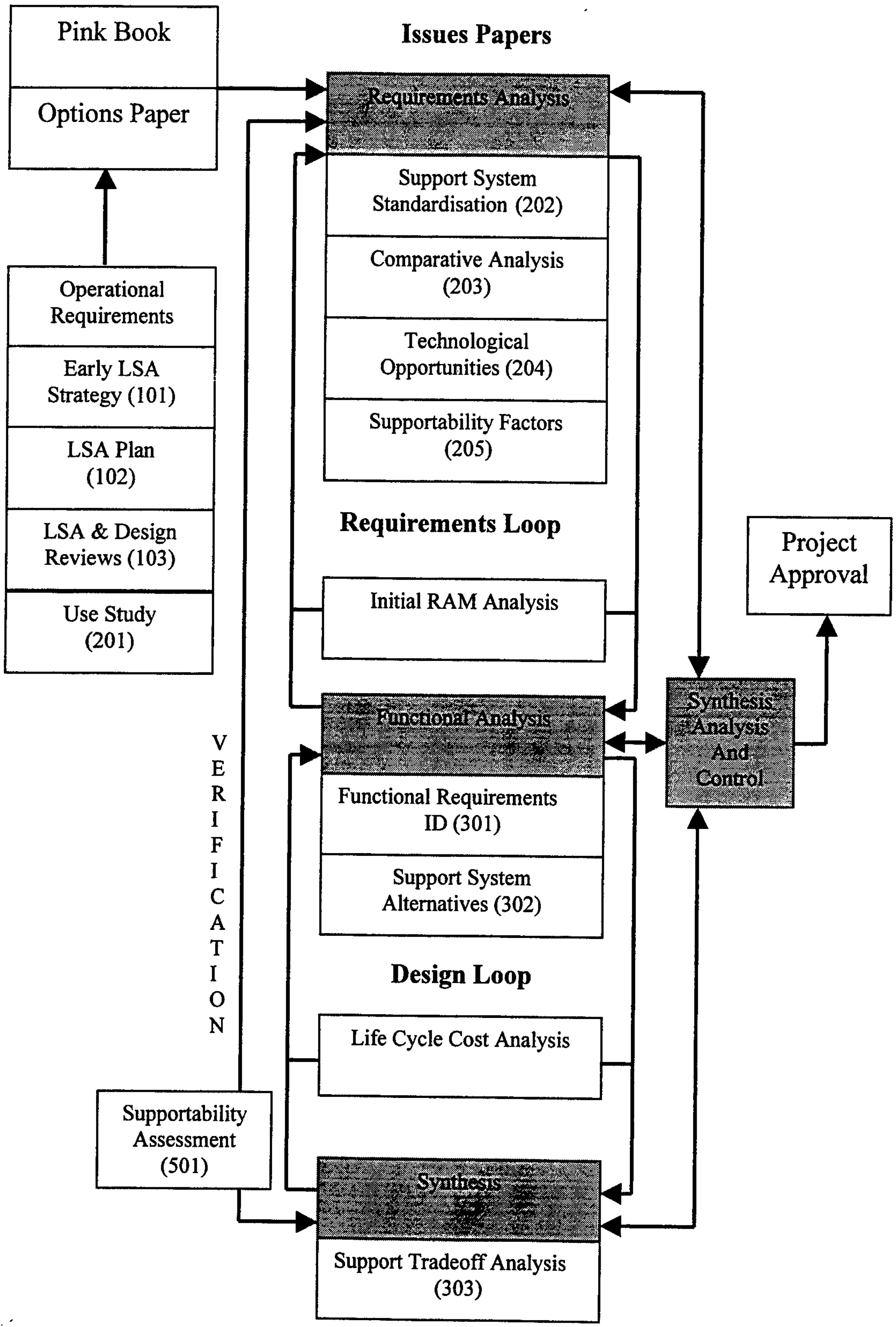

Figure 23. Systems Development Methodology--Issues Paper

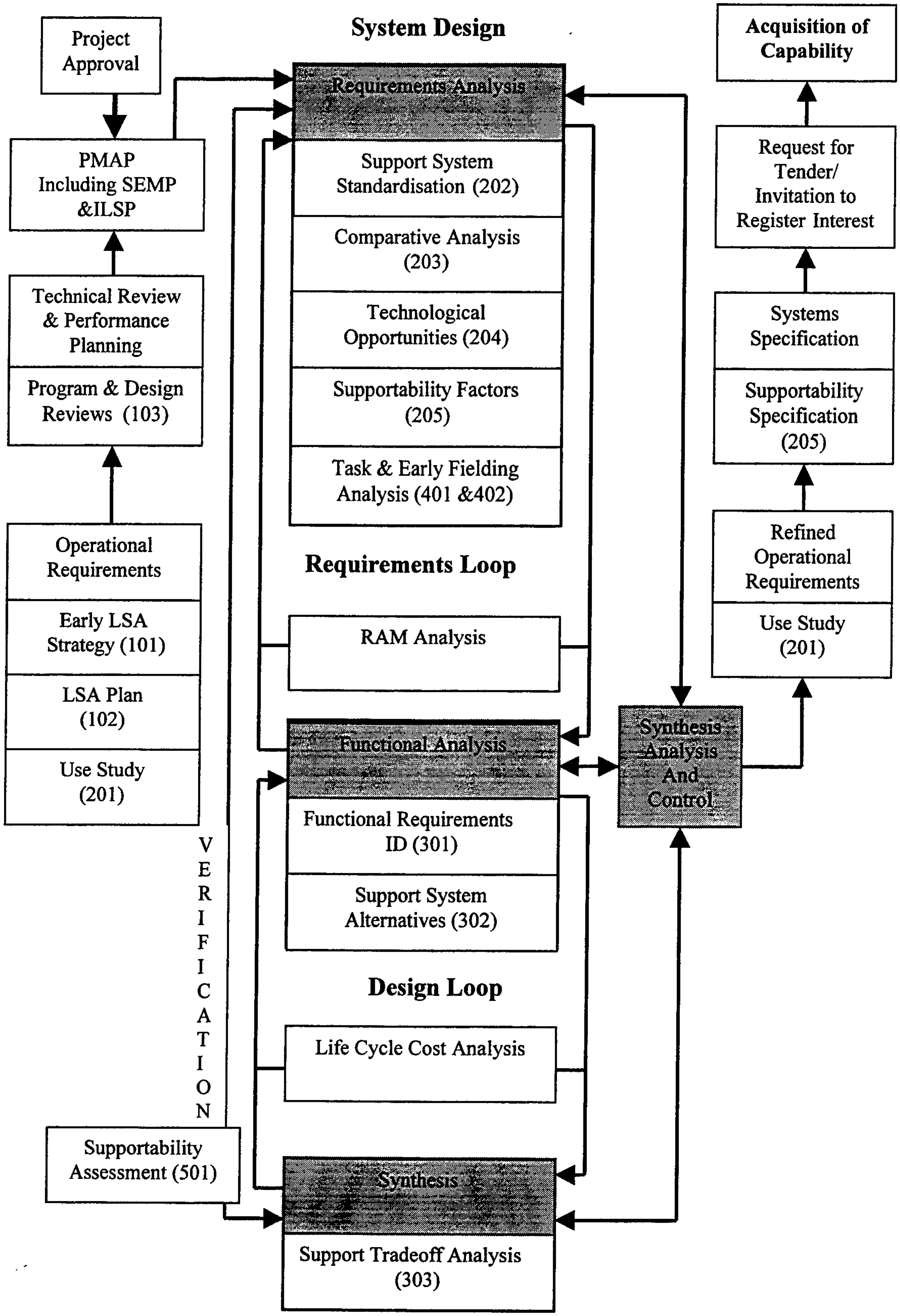

Figure 24. Systems Development Methodology--System Design

Figure 25 outlines the prime responsibility for applying the systems development methodology in the various stages of the concept and acquisition phases. It shows that primary responsibility lies with the Combined Arms Training and Development Centre (CATDC), the Land Development Branch within Capability Development Division (CD Div) and the Defence Acquisition Organisation (DAO).

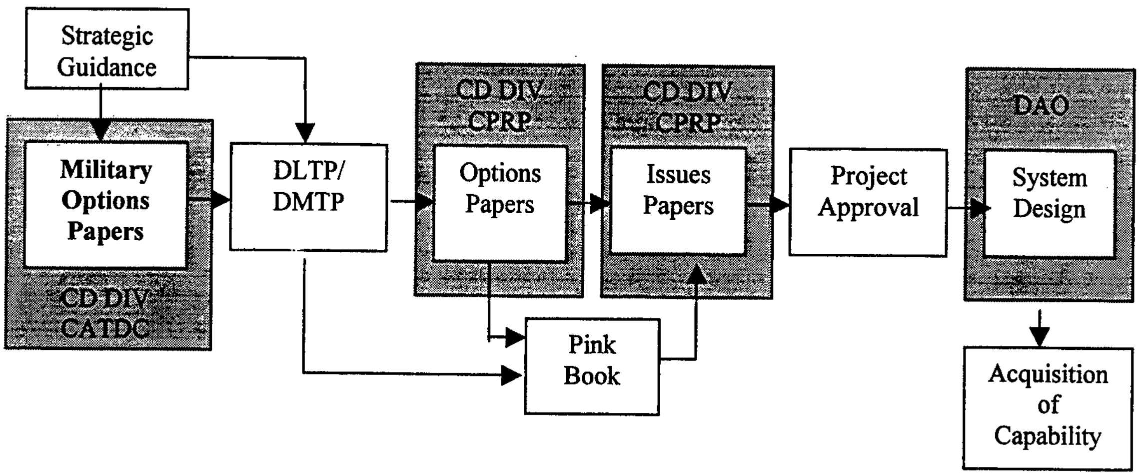

Figure 25. Responsibility for applying the Systems Development Methodology in the Concept and Acquisition Phases

Figures 21 to 25 outline a systems development methodology that the Australian Army could adopt to ensure that a systems approach is applied to the concept and acquisition phases of the materiel cycle. While the Organisational structures and capability development processes within the Australian Defence Force are likely to change in future, the utility of this methodology will remain extant. It provides a "work in progress" that can be adapted to the given Organisations and processes in place at the time.

While use of this methodology would be of direct benefit to the Army, its implementation would pose a number of challenges. It would impose a training liability on the Defence Force. At present neither the CATDC, the Land Development Branch within the CD Div or CPRP have the skills, expertise or experience to apply this methodology. The ability of the DAO to do so is limited. Additional manpower and resources may be required within CATDC, CD Div, CPRP and DAO. The capability development and acquisition process is defence wide, therefore, implementation of the methodology would need to be conducted within the context of the defence capability development processes. In particular, agreement would have to be sought from the members of the Capability Forum and the Defence Capability Committee as they consider and approve key capability development documentation that result from the application of this methodology.

While there are challenges for implementation of this methodology at the present time, its application would ensure that a systems approach was applied to the concept and acquisition phases of the materiel cycle. This would provide long term and lasting benefits that would justify the investment required for its implementation.

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[1]Robert Halligan , *Systems Engineering for Defence and Aerospace: From Concept Exploration to Introduction into Service--ATEA Course Notes*, (Melbourne: Technology Australasia, September 1995), Slide No. 19.

[2]US DoD, *DoD 5000.2-R Mandatory Procedures for Major Defence Acquisition Programs (MDAPs) and Major Automated Information System (MAIS) Acquisition Programs*, (Washington DC: US DoD, 15 March 1996, Part 4 Section 4-3), 1.

[3]Electronic Industries Association, *EIA Standard IS-632--Systems Engineering*, (Washington DC: Electronic Industries Association Engineering Department, December 1994), Figure 3, 8.

[4]Ibid., 9.

[5]Ibid., 9.

[6]Defence Systems Management College, *Systems Engineering Management Guide*, 1983 edition, (Washington DC:. US Government Printing Office,) 6-1.

[7]Technology Australasia, *Standard No. 001 Systems Engineering*, Issue 3, (Melbourne: Technology Australasia, 20 September 1996), 13, Figure 2.

[8]Ibid., 13, Figure 10.

[9]Electronic Industries Association, 10.

[10]Ibid., 11.

[11]Department of Defence Logistics Division, *Logistic Support Manual LOGMAN*, (Canberra: Commonwealth of Australia, October 1996), Amendment 1, Part 1 Section 1, 1-1-3.

[12]Ibid., Part 2 Section 1, Chapter 1, 2-1-1-3.

[13]Ibid., Part 2 Section 1 Chapter 1, 2-2-1-3, 2-1-1-4.

[14]Keith Gascoyne and Peter King, *ILS Awareness Course--Student Notes*, (Canberra: Computer Power and Total Logistics Management, 28 March 1996), 2.

[15]Keith Gascoyne & Peter King, Lesson No BA_19, Figure, 3.

[16]Department of Defence Logistics Division, Part 2 Section 1 Chapter 1, 2-1-2-2.

[17]Department of Defence Logistics Division, Part 2 Section 1 Chapter 1, 2-1-1-5

[18]Keith Gascoyne and Peter King, 6.

[19]Department of Defence Logistics Division, Part 2 Section 4 Chapter 1, Annex A, 2-4-1A-1.

[20]Ibid., Part 2 Section 1 Chapter 1, 2-1-1-5.

[21]TDA Systems Engineering and BALL Aerospace and Technologies Corp, *Defence Acquisition Organization--Systems Engineering Training*, (Canberra: TDA Systems Engineering, Course Notes, 29 September to 1 October 1997), 1-8.

[22]Department of Defence Logistics Division, Part 2 Section 4 Chapter 1, 2-4-1-2.

CHAPTER 5

CONCLUSION, RECOMMENDATIONS, AND SUGGESTIONS FOR FURTHER RESEARCH

Conclusion

A systems approach to capability development must consider all of the requirements influencing the capability being introduced into service. The methodology that the Australian Army should adopt to ensure that a systems approach is applied to the concept and acquisition phases of the materiel cycle is an integration of Systems Engineering, Integrated Logistics Support (ILS), and Logistic Support Analysis (LSA).

Systems Engineering is an interdisciplinary approach that aims to deliver systems providing an optimum, balanced, coherent solution to satisfy customer needs. It is an orderly, structured, disciplined and systematic process. It attacks large problems by breaking them down into smaller ones, and ensures that the solutions of the smaller problems are integrated into the solution of the larger problem. An important aspect of this process is traceability and accountability. The process examines all of the elements that interface with a system. In this way it seeks to optimize the quality of a system throughout its entire life cycle.

As applied to an Army equipment system, Systems Engineering includes but is not limited to, capability development, project management, engineering, and logistics. It is a management or problem solving approach, rather than a technical approach, even though there are specific standards that outline its implementation. The goal of Systems Engineering is to completely and correctly identify and validate the requirements that apply to a capability and to transform them into a description of system elements that best satisfy these requirements. It aims to achieve these goals at a cost equal to or better than

budget and in a total time equal to or better than schedule. The standard that currently has greatest utility for the Australian Defence Force to use as guidance is EIA Standard IS-632. This standard outlines the key activities of Systems Engineering as:

a. Requirements Analysis;

b. Functional Analysis/Allocation;

c. Synthesis; and

d. Systems Analysis and Control.

The ILS is another whole of life management discipline that aims to deliver a complete system that meets user needs. It aims to integrate all support and service considerations for a materiel system and provide a seamless transition of support activities between each phase of the materiel cycle.

Within the concept and acquisition phases, ILS aims to ensure that:

a. consideration of support factors is integral to the development of capability options,

b. support considerations influence design requirements and selection,

c. support requirements are used in optimizing a materiel system's performance,

d. required support elements are acquired or implemented.[1]

LSA provides a single analytical approach to enable support considerations to influence the design requirements and design selection for a materiel system. It is the tool that integrates ILS and the engineering functions. It is made up of a series of tasks that when performed ensures that each element of ILS is considered along with the system design. To carry out ILS you must complete LSA tasks. Therefore, in order to integrate Systems Engineering and ILS you must integrate Systems Engineering and LSA

tasks. The systems development methodology integrates LSA tasks into each of the key activities of the Systems Engineering process. The methodology is tailored to each of the key outputs from the capability development process.

The key outputs from the capability development process are Military Options Papers, Options Papers and Issues Papers in the concept phase, and the system design activities in the acquisition phase (figure 25). The four key organisations for the Army in the concept and acquisition phases of the materiel cycle are the Combined Arms Training and Development Centre (CATDC), the Capability Programming and Resource Planning Division (CPRP), Land Development Branch within the Capability Development Division (CD Div) and the Defence Acquisition Organization (DAO).

CD Div, assisted by the CATDC, is responsible for producing the Military Options papers. CD Div, assisted by CPRP is responsible for producing Options and Issues papers. DAO is responsible for completing the System Design activities.

Figures 21 to 25 outline the responsibility of each of these organisations for applying the systems development methodology. While the organisational structures and capability development processes within the Australian Defense Force are likely to change in future, the utility of this methodology will remain extant. It provides a "work in progress" that can be adapted to the given organisations and processes in place at the time.

Recommendations

It is recommended that:

a. The Land Development Branch within the Capability Development Division and the Combined Arms Training and Development Centre apply an integration

of Systems Engineering, ILS, and LSA as outlined in figure 21, to produce Military Options Papers.

b. The Land Development Branch within the Capability Development Division and the Capability Programming and Resource Planning Division apply an integration of Systems Engineering, ILS, and LSA as outlined in figure 22, to produce Options Papers.

c. The Land Development Branch within the Capability Development Division and the Capability Programming and Resource Planning Division apply an integration of Systems Engineering, ILS, and LSA as outlined in figure 23, to produce Issues Papers.

d. The Defence Acquisition Organisation apply an integration of Systems Engineering, ILS, and LSA as outlined in figure 24, to complete System Design activities.

e. The application of the systems development methodology to Military Options Papers, Options Papers, Issues Papers and Systems Design activities be developed progressively as outlined in figure 25.

Areas for Further Research

There are three areas where further research might add a significant knowledge to this field. The constraints of time and the limited scope of this study precluded their investigation in this paper.

a. How do the findings of the Capability Management Improvement Team (CMIT) affect the implementation of the systems development methodology?

The CMIT aimed to overcome the current segmentation of capability management that currently exists within defense, and achieve a more seamless life cycle management of capability. The outcomes of the team's study are likely to have a major impact on the nature and implementation of the systems development methodology. Further research should examine how implementation of this methodology within the Army would affect defense wide capability development processes.

b. What are the training requirements for implementation of the systems development methodology? A comprehensive training program is likely to be required for the CATDC, CD Div, CPRP and DAO. Without sufficient skills, expertise and experience within these organisations, the systems development methodology will not be able to be sufficiently implemented or maintained.

c. What are the resource and manpower requirements for the implementation of the systems development methodology? Additional resources and manpower are likely to be required for the CATDC, CD Div, CPRP and DAO. This study should examine the appropriate balance between uniformed personnel, public servants and defense contractors. It should also examine the requirement for integrated support systems, such as Systems Engineering software tools and decision support databases.

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[1]Australian Department of Defence, *Defence Instruction (General) LOG 03-6 - Defence Policy on Integrated Logistics Support*, (Canberra: Commonwealth of Australia, 26 May 1997), 1.

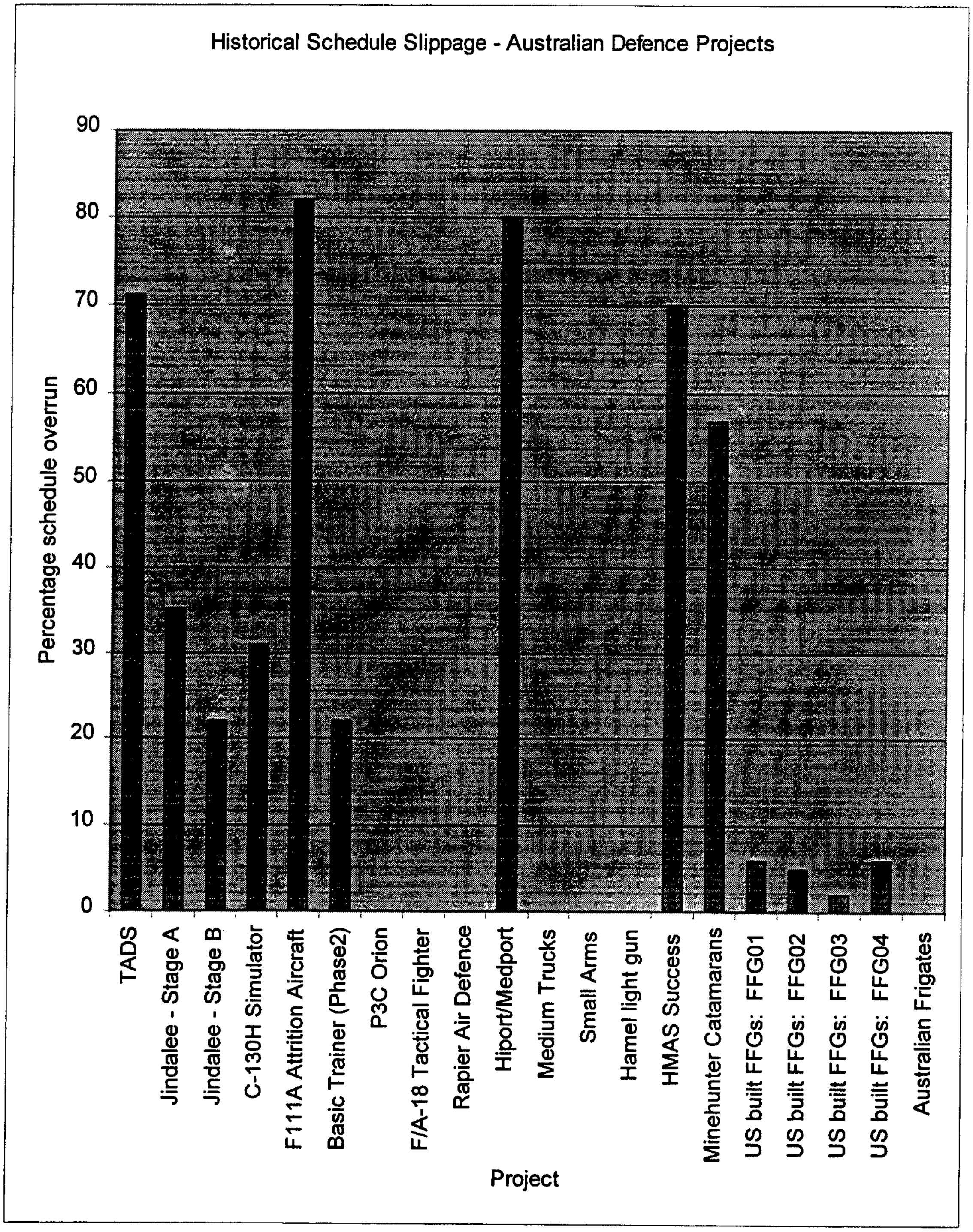
APPENDIX A

HISTORICAL PROJECT DATA--AUSTRALIAN DEFENCE PROJECTS

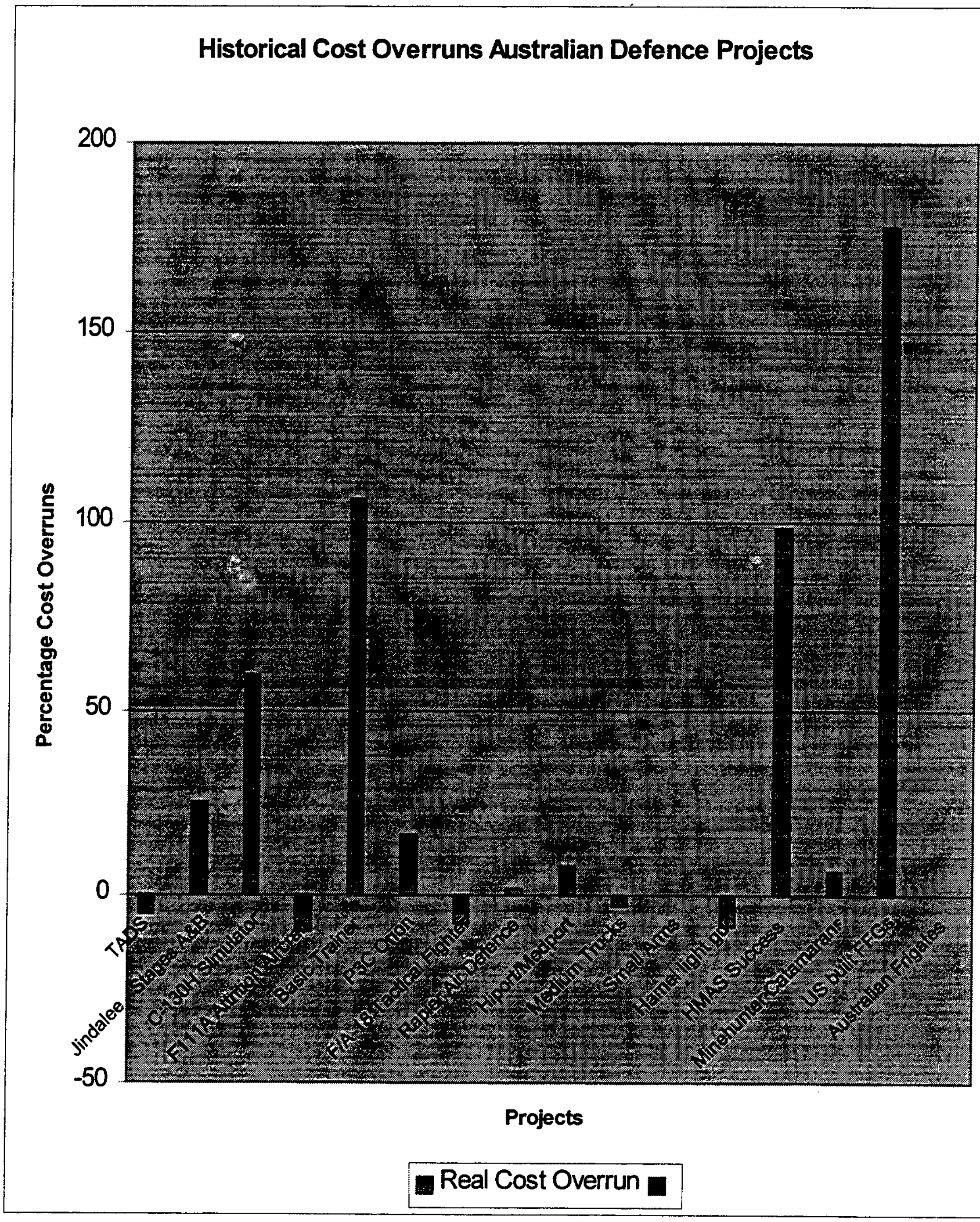
Shown below are the statistics from the Australian Department of Defence showing cost overruns and schedule slippages for sixteen Defence projects.[1]

Schedule Slippages

Project	Percentage schedule overrun
TADS	71
Jindalee - Stage A	35
Jindalee - Stage B	22
C-130H Simulator	31
F111A Attrition Aircraft	82
Basic Trainer (Phase2)	22
P3C Orion	0
F/A-18 Tactical Fighter	0
Rapier Air Defence	0
Hiport/Medport	80
Medium Trucks	0
Small Arms	0
Hamel light gun	0
HMAS Success	70
Minehunter Catamarans	57
US built FFGs: FFG01	6
US built FFGs: FFG02	5
US built FFGs: FFG03	2
US built FFGs: FFG04	6
Australian Frigates	0


Historical Schedule Slippage - Australian Defence Projects
Percentage schedule overrun
0
10
20
30
40
50
60
70
80
90
TADS
Jindalee - Stage A
Jindalee - Stage B
C-130H Simulator
F111A Attrition Aircraft
Basic Trainer (Phase2)
P3C Orion
F/A-18 Tactical Fighter
Rapier Air Defence
Hiport/Medport
Medium Trucks
Small Arms
Hamel light gun
HMAS Success
Minehunter Catamarans
US built FFGs: FFG01
US built FFGs: FFG02
US built FFGs: FFG03
US built FFGs: FFG04
Australian Frigates
Project

Project	Real Cost Overrun
TADS	-5
Jindalee - Stages A&B	25.3
C-130H Simulator	59.6
F111A Attrition Aircraft	-9.7
Basic Trainer (Phases 1 & 2)	106
P3C Orion	16.6
F/A-18 Tactical Fighter	-7.3
Rapier Air Defence (Phases 1 & 2)	1.9
Hiport/Medport	8
Medium Trucks	-2.4
Small Arms (Phases 1 & 2)	0
Hamel light gun (Phases 1,2 & 3)	-8.1
HMAS Success	98.6
Minehunter Catamarans (Phases 1 & 2)	6.6
US built FFGs	177.5
Australian Frigates	0



[1]Department of Defence, Minutes of Evidence, Volume 2, Chapters 2-17 & pages 2825-2828 cited in R. Halligan, 'Systems Engineering for Defence and Aerospace: from concept exploration to introduction into service--ATEA Notes', Technology Australasia, Melbourne, 1995, Additional Notes.

APPENDIX B

LOGISTIC SUPPORT ANALYSIS TASKS

Shown below is a list of the Logistic Support Analysis (LSA) tasks and sub-tasks. LSA should be tailored to each capability by conducting those tasks and sub-tasks relevant to the project.

Task/ Subtasks	Title
101	**Development of an early Logistic Support Analysis Strategy**
101.2.1	Supportability Objectives
101.2.2	Cost Estimate
101.2.3	Updates
102	**Logistic Support Analysis Plan**
102.2.1	LSA Plan
102.2.2	Updates
103	**Program & Design Reviews**
103.2.1	Establish Review Procedures
103.2.2	Design Reviews
103.2.3	Program Reviews
103.2.4	LSA Review
103.2.5	LSA Guidance Conferences
201	**Use Study**
201.2.1	Supportability Factors
201.2.2	Quantitative Factors
201.2.3	Field Visits
201.2.4	Use Study Report & Updates
202	**Mission Hardware, Software and Support System Standardization**
202.2.1	Supportability Constraints
202.2.2	Supportability Characteristics
202.2.3	Recommended Approaches
202.2.4	Risks
203	**Comparative Analysis**
203.2.1	Identify Comparative Systems
203.2.2	Baseline Comparison System
203.2.3	Comparative System Characteristics
203.2.4	Qualitative Supportability Problems
203.2.5	Supportability, Cost and Readiness Drivers
203.2.6	Unique System Drivers
203.2.7	Updates
203.2.8	Risks and Assumptions

Task/ Subtasks	Title
204	**Technological Opportunities**
204.2.1	Recommended Design Objectives
204.2.2	Updates
204.2.3	Risks
205	**Supportability and Supportability Related Design Factors**
205.2.1	Supportability Characteristics
205.2.2	Sensitivity Analysis
205.2.3	Identify Proprietary Data
205.2.4	Supportability Objectives and Associated Risks
205.2.5	Specialisation Requirements
205.2.6	Interoperability (eg. ABCA/NATO) Constraints
205.2.7	Supportability Goals and Thresholds
301	**Functional Requirements**
301.2.1	Functional Requirements
301.2.2	Unique Functional Requirements
301.2.3	Risks
301.2.4	Operations and Maintenance Tasks
301.2.5	Design Alternatives
301.2.6	Updates
302	**Support System Alternatives**
302.2.1	Alternate Support Concepts
302.2.2	Support Concept Updates
302.2.3	Alternative Support Plans
302.2.4	Support Plan Updates
302.2.5	Risks
303	**Evaluation of Alternatives and Tradeoff Analysis**
303.2.1	Tradeoff Criteria
303.2.2	Support System Tradeoffs
303.2.3	System Tradeoffs
303.2.4	Readiness Sensitivities
303.2.5	Manpower and Personnel Tradeoffs
303.2.6	Training Tradeoffs
303.2.7	Level of Repair Analysis
303.2.8	Diagnostic Tradeoffs
303.2.9	Comparative Evaluations
303.2.10	Energy Tradeoffs
303.2.11	Survivability Tradeoffs
303.2.12	Transportability Tradeoffs
303.2.13	Support Facility Tradeoffs

Task/ Subtasks	Title
401	**Task Analysis**
401.2.1	Task Analysis
401.2.2	Analysis Documentation
401.2.3	New/Critical Support Resources
401.2.4	Training Requirements and Recommendations
401.2.5	Design Improvements
401.2.6	Management Plans
401.2.7	Transportability Analysis
401.2.8	Provisioning Requirements
401.2.9	Validation
401.2.10	ILS Output Products
401.2.11	LSAR Updates
401.2.12	Provisioning Screening
402	**Early Fielding Analysis**
402.2.1	New System Impact
402.2.2	Sources of Manpower and Personnel Skills
402.2.3	Impact of Resource Shortfalls
402.2.4	Combat Resource Requirements
402.2.5	Plans for Problem Resolution
403	**Post Production Support Analysis**
403.2	Post Production Support Plan
501	**Supportability Test, Evaluation and Verification**
501.2.1	Test and Evaluation Strategy
501.2.2	System Support Package Component List
501.2.3	Objectives and Criteria
501.2.4	Updates and Corrective Actions
501.2.5	Supportability Assessment Plan (Post Deployment)
501.2.6	Supportability Assessment (Post Deployment)

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